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THE RAINS OF THE NILE BASIN

AND

THE NILE FLOOD OF 1906.

BY

CAPTAIN H. G. LYONS, D.Sc., F.R.S.

DIRECTOR GENERAL, SURVEY DEPARTMENT.

SURVEY DEPARTMENT PAPER, No. 2.

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THE RAINS OF THE NILE BASIN

AND

THE NILE FLOOD OF 1906.

CHAPTER I.

INTRODUCTION.

The series of seven dry years which began with the exceptionally low flood of 1899 when the volume discharged by the Nile was 37 per cent below the average, and ended with that of 1905 which was 35 per cent deficient, was succeeded this year by a flood which was more nearly of average volume.

Year by year it is possible to supplement existing information by newer and more ample data, and to fill gaps in the chain of conditions which lead up to the summer rains of Abyssinia, the feeders of the Nile flood. A few years ago the resemblance between the gauge curve of a rising flood and that of some former year was used as the only means of anticipating its probable development; then it was suggested that the Bombay rainfall might be utilized as a basis of prediction, but with the re-opening of the Sudan and the establishment of meteorological stations there, supplemented by others in the equatorial regions, our knowledge has rapidly increased, and deductions from accurate observations have largely replaced empirical methods. To-day we can follow the northward extension of the rains of tropical East Africa from Mauritius and Zomba (in British Central Africa) which lie just within the southern tropic, through German East Africa up to the lake plateau. In the Seychelles Islands of the Indian Ocean and in British East Africa and Uganda, we note them as they pass on to the Somali Coast and to the Bahr el Jebel. Further north again, a chain of meteorological stations now supplies full information about the intensity and the extension of the rains from the Nile-Congo watershed through the Bahr el Ghazal, and along the Bahr el Jebel and the Sobat across the Sudan plains to the limits of the Monsoon region near Dongola and Berber; to the south of the Abyssinian tableland information is still meagre, and we are dependent on the journals of the few travellers who have traversed the region.

In Abyssinia itself, more systematic study of the meteorological conditions is urgently needed. When the heavy rainfall of July and

August has set in, the conditions of the surrounding regions seem to give but slight indications of the variations which take place on the tableland, and as 30 per cent of the total rainfall falls in each of these months, a break in the rains lasting for 10 days may reduce the volume of the Nile flood by 10 per cent. At Addis Abbaba alone is the rainfall measured at present, and it is not yet possible to get observations from places lying further to the west, which are thus more representative of the Blue Nile basin. In 1907 a qualified meteorologist will be sent to Addis Abbaba in order to study the local conditions on the plateau during June, July, August and September.

It is also proposed to investigate the upper region of the Monsoon current over the Sudan plains by means of kites carrying self-registering apparatus, but this work which was to have been commenced in 1907 is now unavoidably postponed till 1908.

The Nile has presented several features of special interest during the past year. In both February and March, heavy rainstorms occurred in Abyssinia and the Southern Sudan, which raised the river levels and greatly improved the low stage supply of the spring months; the steady improvement in the rainfall of August and September furnished a flood about 10 per cent below the average while the maximum gauge readings at Wadi Halfa just exceeded the mean, a great improvement on the conditions experienced during the past seven years. We have therefore a flood of nearly normal volume to study, and our task is greatly facilitated by the new river gauges built in masonry which have been constructed by the Sudan Irrigation Service to take the place of temporary gauges.

The river gauges which exist at the present time are given in the following table :—

TABLE I.—Lake and River Gauges in the Nile Basin.

Portion of Basin.	Place.	Nature of Gauge.	Approx. Reading of low stage.	Level of zero above sea-level.*	Remarks.
			m.	m.	
Lake Victoria... ...	Kisumu	.....	0·00	1135	Approx.
	Jinja...	.....	0·30	1135	"
	Entebbe	.....	0·15	1134	"
Lake Albert...	Butiaba	.....	1·25	?	
Bahr el Jebel	Wadelai	Brick well ...	...	?	
	Gondokoro	Masonry	...	?	
	Mongalla...	"	0·90	?	
	Bor Mission Station.	Wooden or Iron?	1·40	?	
	Bor	Masonry	1·30	?	
	Ghaba Shambe ...	Iron plate... ...	1·20	?	
Bahr el Ghazal (Jur. R.)	Wau	Wooden	0·60	?	

TABLE I.—LAKE AND RIVER GAUGES IN THE NILE BASIN (*continued.*)

PORTION OF BASIN.	PLACE.	NATURE OF GAUGE.	Approx. Reading of low stage.	Level of zero above sea-level.*	REMARKS.
			m.	m.	
Bahr el Ghazal (cont.)	Meshra er Rek	Wooden	8·55	?	
White Nile	Attigo	Masonry	11·90	373·50	
	Taufikia	,, ...	9·75	373·50	
	Kodok	,, ...	10·00	372·00	
	Melut	,, ...	10·00	370·50	
	Renk	,, ...	10·00	367·00	
	Goz Abu Guma ...	,, ...	10·10	363·50	
	Dueim	,, ...	9·60	362·25	
	Geteina	,, ...	10·10	361·50	
River Sobat	Gambela (R. Baro) ...	Wooden	0·00	?	
	Tawfot	,, ...	0·60	?	
	Doleib Hilla	Masonry	10·30	?	
	Abwong	,, ...	10·00	?	
Blue Nile	Roseires	Masonry	8·90	426·59	
	Singa	,, ...	10·50	402·29	
	Sennar	,, ...	7·80	394·29	
	Wad Medani	,, ...	7·80	376·79	
	Kamlin	,, ...	10·00	368·59	
	Khartoum	,, ...	10·00	364·37	
River Atbara	Khashm el Girba ...	Cut on rock ...	9·00	...	
Nile	Berber	Masonry	0·40	338·45	
	Sarras	Painted on rock.	0·50	132·79	
	Wadi Halfa	Masonry	0·60	116·70	
	Aswan	,, ...	85·00	84·16	

* The zero of Khartoum gauge being 364·37 metres above mean sea-level at Alexandria, as determined by recent levelling.

In the course of 1906 the rainfall was measured at several stations where previously rainy days alone were recorded, since Mr. C. E. Dupuis, Inspector General of Sudan Irrigation, made the necessary arrangements for doing so. The number of stations at which the rainfall was recorded at the end of 1906 was :—

TABLE II.

	Rainfall measured.		Rainy days recorded.	
	1905	1906	1905	1906
Egypt	16	23	...	...
Sudan Plains and Blue Nile	21	30	27	25
Sobat, Bahr el Jebel and Bahr el Ghazal.	10	16	8	7
Data received from the following stations has also been utilized:—				
Eritrea and Abyssinia	6	6	...	...
Uganda	8	8	...	...
British East Africa	20	34	...	...
German East Africa	9	9	...	...
British Central Africa	1	1	...	...
Seychelles	Not used	1	...	...
Mauritius		1	...	...

I would most gratefully acknowledge the generous manner in which information has been contributed from Eritrea, Addis Abbaba, Uganda, British East Africa, German East Africa, British Central Africa and by Dr. G. Walker, F. R. S., Director General of Observatories to the Government of India, and Dr. Claxton, Director of the Royal Alfred Observatory at Mauritius. The rainfall, which was communicated daily by telegraph in August and September by Colonel Sir John Harrington, K.C.M.G., from Addis Abbaba, and by Captain Tancredi from Addi Ugri, enabled correct forecasts of the flood to be made at a time when other information gave but an ambiguous clue to the development of the rains.

The rains were somewhat late in reaching the Sudan plains and were at first rather weak; in July an improvement took place, which was maintained in August and the early part of September, so that the flood on the whole was fairly satisfactory, and as gauged by the estimated volume passing Aswan, reached 0·87 of an average flood. From this it may be considered as about equal to the floods of 1900 and 1901, but coming as it did, immediately after good low-stage levels (see p. 57) and increasing to a somewhat late maximum, it may be characterized as fairly good rather than moderate only.

From May onwards, public opinion strongly inclined to the view that the flood would be an exceptionally large one, as the favourable low-stage levels, due to abnormal rainfall in February and March, were generally interpreted as the result of an early and unusual development of the summer rains, but the meteorological conditions in the regions south of the Sudan never lent any support to this view, indeed, in May the prospect was distinctly unfavourable, and it was not until after June that a decided improvement was discernible.

CHAPTER II.

The Normal Distribution of the Rainfall.

The seasonal distribution of the rainfall over the tropical region of East Africa exhibits the regularity usual in this region, where no high mountain ranges prevent the free movement of the air currents. The relief of the eastern half of Africa lying between the tropics may, if local features are neglected, be described as a belt of high land 1,000 to 1,200 kilometres wide, and from 1,000 to 2,000 metres above sea-level, extending from the southern end of Lake Nyassa to the northern part of Eritrea. A lower belt 500 to 600 kilometres wide separates it from the Indian Ocean on the east, while to the west extend the low-lying basins of the Upper Congo and the Nile.

At the southern limit of this tropical belt, the rains reach their maximum in January, and afterward move gradually northwards, following the sun's apparent change of position until in July and August, the Abyssinian plateau receives two-thirds of its total rainfall. After this, the rains retreat southwards, falling heavily on the southern tropic about the end of the year.

In consequence of the gradual shift of the rainy season, it is not easy to prepare a map which will show the seasonal rainfall satisfactorily; while one region is adequately represented, those to the south and north of it exhibit the later and earlier features of their precipitation respectively. Last year*, in describing the average distribution of the rainfall, I gave monthly rainfall maps so far as the available data allowed. In the present Report, the seasonal and annual distribution are given on Plate II, *a*, *b*, *c*, and *d*. In Plate II, *b*, the rainfall of June-September is shown, being that which supplies the Nile flood and is of primary importance to the Sudan. Plate II, *a*, shows the distribution for the period March-May, which corresponds to the first rainy season of the Lake plateau, while in Plate II, *c*, is that of October-December, the second rainy season of the Lake plateau.

In this grouping, the upper part of the Bahr el Jebel and North Uganda where the rains practically continue from May to October, and British Central Africa with its rains from December to March, are not

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* "The Rains of the Nile Basin for 1905," Survey Department, Cairo, 1906.

well represented, while the rains of German East Africa are often heavy in February.

The general march of the rains during the year is briefly described in the following paragraphs, while the mean values are given in the Table III (p. 16-19).

January.—In this month the rainfall at Zomba and generally in the southern portion of British Central Africa is at its maximum, as well as at Mauritius and Lorenzo Marquez. In the southern part of the equatorial belt, the rainfall is less than in December, but is still considerable. North of the Albert Lake practically none falls.

February.—Rains are still at a maximum in British Central Africa, and tend to increase in the southern part of German East Africa, but they have reached a secondary minimum in British East Africa and round the Victoria Lake, while to the north of this, dry conditions and clear skies prevail.

March.—In the south, the rains diminish slightly, in German East Africa the maximum is recorded at inland stations such as Tabora, and at Ujiji on Lake Tanganika, while a general increase takes place over all the Equatorial Region, and extends as far as lat. 5° N. on the Bahr el Jebel.

April and May form the principal rainy season of the equatorial belt, and at both coast and inland stations from 200 to 400 millimetres per month are recorded. The southerly winds have now extended northwards as far as the valley of the Sobat, and the annual monsoon rains have begun to fall up to this point, but are not as yet heavy, except on the upper reaches of the Bahr el Jebel where about 150 millimetres a month fall, and on the southern tableland of Abyssinia where actual measurements are wanting, but all acounts agree in describing the April-May rains as heavy with intervals of fine weather.

The first light rains, "Azmera," of Abyssinia are now falling, but they are of local importance only, and do not affect the rivers much until the latter half of May.

June.—By this time the low pressure centre which occupies the north-western portion of India from June to September has developed, and the gradient from the Nile Valley eastwards towards the Persian Gulf is well defined. In connection with this the southerly winds

rapidly extend to lat. 16° N. and the monsoon rains set in over the Sudan plains, the Abyssinian tableland and in Eritrea. The Blue Nile and the Sobat are rising steadily, fed by a rainfall of 150 to 200 millimetres. Such data as exist seem to show that about 15 per cent of the monsoon rainfall of Abyssinia falls in this month.

July and August are the dry seasons in the Equatorial belt, but they include the height of the monsoon rainfall in the Sudan and Abyssinia as well as in India. Over 60 per cent of the rainfall of the year falls in these two months, and the Nile flood is directly determined by it.

In *September* the rains at first moderate, and usually by the middle of the month diminish very markedly except in Southern Abyssinia, where they last rather longer than in the north. The southward retreat of the rains has now begun, and with it the second maximum on the Upper Bahr el Jebel usually occurs.

In *October* the rains north of lat. 6° N. are unimportant, though they are fairly heavy to the south of this, and in this month the autumn maximum occurs at Wadelai. On the Lake plateau rains increase as the autumn wet season sets in, and a considerable amount falls at most stations. The dry northerly winds are now pressing southwards, and the coast rains are less than in the spring.

November is usually the month of heaviest rainfall in the equatorial region, but at some stations *December* seems to approach or even exceed it. In German East Africa the latter is considerably the more important, while at Zomba it is almost equal to January and February, and forms with them the rainy season of the summer tropic.

In the following table the mean rainfall is given for a series of stations in and near the Nile basin, where one year's observations at least are available.

TABLE III.

Mean Monthly Rainfall in Millimetres.

A.—Stations near but not in the Nile Basin.

STATIONS.	YEARS.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	YEAR.
Mauritius	30	106	192	252	114	80	53	61	68	35	32	48	123	1164
Seychelles	16	459	308	278	177	156	140	62	74	129	127	288	378	2576
British Centr. Africa:														
Zomba	12	283	292	206	93	18	12	8	3	8	44	137	278	1382
German East Africa:														
Lindi	10 8/12	154	105	180	149	35	1	8	11	14	11	47	115	830
Dar es Salam	13 7/12	94	53	132	312	207	28	41	29	32	34	80	112	1154
Morogoro Tal	2 3/12	127	78	244	338	106	44	38	19	16	17	44	163	1234
Kilossa	9 6/12	97	107	123	149	52	7	19	15	12	19	51	62	713
Mpapua	4 2/12	95	116	158	72	12	0	2	0	0	0	27	137	619
Tabora	9	146	132	169	133	21	4	0	0	7	12	82	146	852
Ujiji	4 7/12	108	125	155	129	32	6	0	0	12	41	104	110	822
Tanga	13 1/12	46	43	105	288	342	64	109	79	84	86	229	68	1543
Kwai	5 11/12	72	69	120	84	121	22	42	8	9	42	131	96	816
British East Africa:														
Zanzibar...	26	86	35	165	264	270	27	70	48	52	76	236	70	1399
Mombasa	16 8/12	22	24	68	186	351	101	81	56	53	73	138	58	1211
Takaungu	14 3/12	10	17	58	133	378	106	102	49	49	65	110	24	1101
Malindi	15 2/12	8	6	25	164	361	130	97	36	39	64	99	23	1052
Golbanti...	2 6/12	11	18	95	68	196	87	84	66	80	59	64	68	896
Kismayu	12 6/12	1	1	6	44	136	92	49	20	19	4	19	7	398
Lamu	1 2/12	0	1	82	295	751	471	38	51	7	7	36	22	1761
Mazeras	2 8/12	76	32	107	268	372	198	108	45	80	64	180	306	1836
Shimoni	13 9/12	35	22	95	262	400	129	113	62	57	49	153	58	1435
Makindu { Govt. Farm... ...	2 2/12	8	41	156	48	50	1	0	0	0	48	335	202	889
Makindu { Railway Station.	2	3	46	204	86	22	0	0	0	1	16	184	48	610
Machakos	12 9/12	33	75	143	216	64	18	5	10	5	55	208	118	950
Nairobi { Govt. Farm... ...	7	46	120	131	201	132	54	19	26	15	59	124	92	1019
Nairobi { Railway Station.	2 11/12	29	50	193	244	137	32	12	27	14	77	128	80	1023
Nairobi { Sub. Comr. House.	1 6/12	52	54	265	312	158	44	12	22	21	63	145	107	1255
Naivasha { Govt. Farm... ...	2 11/12	18	36	126	151	95	38	30	54	47	36	61	96	788
Naivasha { Railway Station.	3	23	43	155	132	28	20	22	72	80	66	102	87	830
Fort Hall	6	23	86	152	309	112	66	24	22	21	136	187	70	1208
Nakuru	3	17	17	141	86	99	54	64	88	47	79	60	42	794
Kikuyu	13 3/12	38	89	168	243	183	68	26	19	37	46	133	94	1144
Molo	3	68	69	199	228	204	126	96	365	110	124	92	73	1754
Eldama Ravine	5 11/12	33	78	108	129	117	100	80	88	60	49	50	41	933
Mwatate...	3	51	48	111	111	64	13	4	8	18	15	106	66	615
Nyeri	2	26	44	87	142	181	18	16	34	20	84	139	129	920
Athi River	3	19	48	270	143	49	7	2	31	0	78	99	35	781
Kitui	3	21	18	204	212	75	9	2	1	1	70	362	112	1087
Voi	2 6/12	43	50	190	136	53	42	4	0	22	10	198	176	924
Mackinnon Road... ...	3	65	55	131	159	109	61	30	22	38	18	137	126	951

TABLE III (*continued.*)

Mean Monthly Rainfall in Millimetres.

B.—STATIONS WITHIN THE NILE BASIN.

STATIONS.	YEARS.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	YEAR.
German East Africa:						LAKE PLATEAU BASIN.								
Muanza	6 5/12	61	96	179	**234**	72	44	2	44	44	79	**126**	125	1106
Shirati	4 7/12	56	63	91	**146**	126	39	12	8	19	43	55	**88**	746
Bukoba	8	107	130	217	**391**	245	46	19	56	67	104	**219**	165	1766
British East Africa:														
Lumbwa...	2 9/12	57	103	190	206	**254**	177	**199**	151	122	127	32	106	1724
Muhoroni	2 11/12	103	172	253	259	**289**	110	61	192	149	149	129	217	2083
Nandi	2 7/12	135	74	**339**	266	318	108	**178**	159	151	139	62	94	2023
Kisumu	7 7/12	69	**161**	148	155	114	85	45	64	73	82	129	**185**	1310
Port Florence	4	78	164	**216**	151	131	112	46	84	66	90	97	**229**	1464
Mumias	10 9/12	72	98	130	**221**	210	190	157	161	**170**	148	153	99	1809
Kericho	2 7/12	92	146	**318**	240	200	130	131	**216**	125	164	119	130	2011
Uganda:														
Jinja	5	67	71	128	**176**	119	68	50	**114**	68	112	113	80	1166
Entebbe	8 5/12	76	91	179	**238**	167	129	68	77	81	94	**158**	145	1503
Natete	7 2/12	60	110	114	**187**	122	72	85	73	99	**133**	92	42	1189
Sesse Island	1 3/12	143	93	255	226	**380**	94	135	110	89	142	**323**	246	2236
Masaka	4 3/12	55	89	134	**225**	173	53	46	57	119	**134**	114	132	1331
Mbarara	4 9/12	92	111	**230**	164	94	32	28	128	185	235	**237**	172	1768
Fort Portal (Toru) ...	4 1/12	34	81	**166**	130	134	113	82	116	196	**226**	135	58	1471
Butiaba	2 11/12	20	31	99	134	**144**	108	50	107	63	**129**	111	69	1065
Bahr el Jebel:						BAHR EL JEBEL AND BAHR EL GHAZAL BASINS.								
Wadelai	8 1/12	24	36	114	94	**119**	94	99	117	102	**168**	113	32	1112
Nimule	3	2	12	103	51	139	68	121	117	131	**153**	119	27	1043
Gondokoro	6 5/12	5	19	69	82	**164**	100	145	141	152	141	43	12	1073
Lado	1 7/12	0	0	27	136	87	151	**218**	129	122	56	20	2	948
Mongalla	3 9/12	3	39	51	103	93	138	111	**157**	97	140	35	4	971
Bor	1 8/12	0	59	50	36	78	80	128	136	**197**	74	34	16	888
Ghaba Shambe	3 4/12	0	40	6	17	76	45	126	126	**141**	80	6	0	663
Bahr el Ghazal:														
Wau...	3	4	25	15	20	102	172	96	185	116	72	37	0	844
River Baro:						SOBAT BASIN.								
Gambela...	1 5/12	17	37	123	60	148	188	116	**246**	224	74	70	2	1305

TABLE III (*continued.*)

Mean Monthly Rainfall in Millimetres.

B.—STATIONS WITHIN THE NILE BASIN (*continued.*)

STATIONS.	YEARS.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	YEAR.
River Sobat:														
Nasser (Tawfot since 17·11·05)	2 9/12	1	35	13	19	71	133	146	194	97	50	13	0	772
Doleib Hilla...	3 8/12	0	24	19	24	77	132	152	146	125	69	30	0	802
							WHITE NILE BASIN.							
Kordofan:														
El Obeid...	4 6/12	0	0	4	0	2	50	112	102	60	24	0	0	354
White Nile:														
Kodok	6 5/12	0	2	2	16	57	138	120	207	102	69	6	0	719
El Dueim	4 10/12	0	0	6	0	21	14	86	87	53	15	0	0	282
Geteina	1 4/12	0	0	very little	0	0	18	36	46	13	16	0	0	129
Khartoum, Hopital ...	8	0	0	0	0	4	22	32	42	12	11	0	0	123
							BLUE NILE BASIN.							
Blue Nile:														
Addis Abbaba*	7 9/12	9	48	105	85	78	146	305	292	161	14	13	3	1259
Roseires	3 3/12	0	0	4	1	45	141	220	197	156	24	9	0	797
Abu Naama, etc.... ...	1 5/12	0	0	1	3	0	75	200	295	102	20	0	0	696
Singa	1 6/12	0	0	light	0	30	120	108	168	46	8	0	0	480
Sennar	1 6/12	0	0	0	0	0	58	140	130	65	31	4	0	428
Wad Medani...	5	0	0	0	0	20	43	127	129	76	13	2	0	410
Mesellemia	1 6/12	0	0	0	0	0	0	57	58	46	0	0	0	161
Managil	1 7/12	0	0	0	0	11	25	46	86	88	30	2	0	288
Rufaa	1 6/12	0	0	0	4	0	4	58	86	74	30	0	0	256
Kamlin	1 6/12	0	0	0	0	0	0	26	28	44	24	1	0	123
Abu Deleig	1 6/12	0	0	0	0	0	8	31	74	64	22	0	0	199
							ATBARA AND GASH BASINS.							
R. Atbara:†														
Gondar	3	0	0	0	0	67	122	290	372	103	46	14	0	1014
Gallabat...	3 7/12	0	3	5	1	40	124	195	246	155	68	4	0	841
Gedaref	3 7/12	0	0	11	0	25	72	175	198	106	13	12	0	612
Khashm el Girba... ...	4 2/12	...	...	...	...	...	20	140	120	50	22	0	0	[352]
Khor el Gash:‡														
Chenefena	2 6/12	...	...	4	6	35	36	96	122	30	6	55	0	[390]
Keren	5 3/12	0	3	2	9	25	107	107	300	79	2	7	0	641
Asmara	2 3/12	2	4	12	14	18	44	134	114	16	30	15	0	403
Addi Ugri	9 8/12	0	6	12	22	38	67	153	179	37	10	10	4	538
Kassala	7	0	1	0	1	6	22	71	105	64	23	0	0	293

* Strictly in the Hawash basin but is not far from the watershed.

† Lower course of Takazze and Settit rivers.

‡ Lower course of River Mareb.

TABLE III (*continued*).

Mean Monthly Rainfall in Millimetres.

C.—Red Sea Coast.

STATIONS.	YEARS.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	YEAR.
Aden	26	11	7	15	5	4	3	1	3	3	0	3	3	58
Massaua	3 4/12	15	13	12	40	0	0	0	4	5	2	8	18	117
Ghinda	5	67	102	103	24	13	6	48	61	12	32	70	73	611
Suakin	16 9/12	26	9	1	1	1	0	3	0	0	37	88	51	217
Erkowit	1 2/12	155	12	0	0	0	1	23	8	4	0	227	132	562

D.—Stations in Upper and Lower Egypt.

STATIONS.	YEARS.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	YEAR.
Cairo: Helwan	3	6	1	2	1	3	0	0	0	0	1	1	2	17
Cairo: Giza	4 11/12	3	4	3	2	1	0	0	0	0	1	0	4	18
Cairo: Abbassia	20	8	5	4	2	2	0	0	0	0	1	4	7	33
Suez	20 1/12	7	3	2	2	1	0	0	0	0	0	1	4	20
Ismailia	21	10	6	6	3	5	0	0	0	0	2	5	11	48
Port-Said	21	21	9	10	5	1	0	0	0	0	2	12	22	82

E.—Stations in Beheira Province and west of the Nile Delta.

STATIONS.	YEARS.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	YEAR.
Mersa Matruh	2 1/12	17	30	8	0	0	0	0	0	0	0	14	32	101
Ras el Kanais	1 9/12	55	65	5	0	32	0	3	0	0	6	52	28	246
Alexandria...	38 10/12	59	31	16	3	1	0	0	0	2	8	38	63	221
Mex	2 2/12	43	24	6	0	13	0	0	0	0	21	47	58	212
Kafr Dawar	2 3/12	28	35	6	3	12	0	0	0	0	30	24	64	202
Abu Hommos	2 3/12	13	26	6	4	8	0	0	0	0	18	14	41	130
Atf	2 3/12	20	30	12	6	3	0	0	0	0	13	20	34	138
Damanhur...	2 4/12	15	18	11	4	8	0	0	0	0	10	10	31	107
Shubrakhit	2 2/12	16	17	8	5	12	0	0	0	0	8	6	34	106
Teh el Barud	2 2/12	6	13	8	2	2	0	0	0	0	5	7	19	62
Kafr Bulin...	2 2/12	9	9	8	2	7	0	0	0	0	1	6	18	60
Khatatba	2 2/12	6	3	3	0	2	0	0	0	0	2	0	5	21
Hosh Issa	2 2/12	10	15	7	6	9	0	0	0	0	12	15	24	98

TABLE IV.

Beheira Province Winter Rains in Millimetres.

MONTHS.	Mersa Matruh.	Alexandria.	Mex.	Kafr Dawar.	Abu Hommos.	Atf.	Damanhur.	Shubrakhit.	Teh el Barud.	Kafr Bulin.	Khatatba.	Hosh Issa.
Total December 1902.—March 1903	...	230	...	...	...	...	...	...	...	...	...	...
„ November 1903.—March 1904	...	110	95	70	58	63	44	40	33	44	28	34
„ October 1904.—March 1905	...	194	247	248	124	177	111	112	80	82	22	112
„ October 1905.—March 1906	107	276	256	230	168	137	139	120	51	39	11	78

CHAPTER III.

The Rainfall of 1906.

The rainfall at Zomba in British Central Africa had been heavy in November 1905, being 81 % above the average, but in December it fell nearly to the normal, and in January, February and March, was far below it. Other inland stations to the north experienced the same deficiency in January, *e.g.* Kilossa, Tabora and Ujiji, while the inland stations further north as far as the Equator were nearly all more or less in defect. The coast stations had rain up to the average, or slightly above it.

In February the southern inland stations of Zomba, Kilossa and Tabora were also deficient, especially the first, but at the coast stations and throughout British East Africa and Uganda, there was a considerable excess. In this month there occurred the first of the rainstorms which so effectively improved the low-stage conditions of the Nile, and staved off the shortage of water in Egypt in May, June, and July, which, but for these storms, would have been inevitable. Meteorological and rainfall stations are still sparsely scattered over a vast area in the Sudan, and we have to piece together information to form such an account as can be made. At Wadelai the rainfall was 55 mm. above the average, and heavy falls occurred on the 12th, 19th and 20th. At Gondokoro an excess of 61 mm. was mostly due to rain which fell on the 13th and 19th. At Ghaba Shambe 119 mm. fell during the month, being 79 mm. above the average. At Wau, in the Bahr el Ghazal, 62 mm. fell, being 37 mm. above the average of three years. At Deim Zubeir, further west, heavy rain was recorded on the 20th, and on the Bahr el Arab heavy rain was reported on two days, though this season of the year is usually dry and fine. On the Sobat heavy rain, 105 mm., much above the average, fell at Tawfot near Nasser, but only 37 mm. at Gambela; 72 mm. were measured at Doleib Hilla of which 67 fell on the 18th. At Addis Abbaba, 108 mm. more than the average fell, but none was recorded at Roseires, to the west of the Abyssinian tableland.

In March also a similar storm occurred, and we note large excess rainfall at Nimule, Gondokoro, Gambela and Addis Abbaba, while at Wadelai, Bor, Wau, Melut, Dueim, Gallabat and Gedaref, it was above the average.

April and May form the first and principal rainy season in the equatorial belt of Eastern Africa, and in both months the rainfall was exceptionally heavy, the excess extending further inland than in 1905. In the region of the Upper Congo, the same conditions prevailed, and Frobenius * states that villages in this region, which are usually high and dry, were flooded in April 1906, and the inhabitants were obliged to build their huts on piles and to use canoes for communication between village and village.

With this abnormal precipitation in the equatorial regions, the northward extension of the southerly winds was weak and slow, and on the White Nile (latitude 10° N.) they had not yet set in definitely by the beginning of May, and at Dueim (lat. 14° N.) they were only recorded on two or three days in April, the rains being therefore below the average.

This was the more noticeable as the rainfall in the southern portion of the basin had been excessively heavy in the earlier months, but such local excess has, in all probability, much to do with delaying and weakening the monsoon rains to the northward, as the same effect has been observed in previous years.

In April, while the Zanzibar rainfall was 67 % above the average, that of Entebbe was 44 % above it, so that the Victoria lake was abnormally high, being in fact on April 30 about 0·50 metre above the mean annual level (1896-1902) and 0·02 metre below the highest level recorded at any time during this period.

In May, rainfall was again in excess on the coast near Zanzibar and Mombasa, but somewhat in defect at most stations on the plateau of British East Africa and on the north of Lake Victoria.

Thus, while the inland rainfall moderated, that on the coast and the Indian Ocean was maintained, and at the Sudan and Abyssinian stations deficiencies were reported.

The rainfall during June was above the average at Zanzibar, and the coast stations of Mombasa, Takaungu, Malindi, Kisimayu and Shimoni, but further inland it was in defect, except at some stations round Lake Victoria. It was average at Wau in the Bahr el Ghazal and at Gondokoro on the Bahr el Jebel, and somewhat in excess at Wadelai.

On the White Nile rain is never heavy in June, and the amounts recorded this year vary considerably, being in excess at Dueim and deficient at Khartoum, while at El Obeid in Kordofan it was unusually heavy.

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* "Zeitschrift der Gesellschaft für Erdkunde" Berlin, 1906, p. 495.

On the Blue Nile the rainfall was above the average at Roseires, and below it at Wad Medani, while at Gallabat and Gedaref it was about normal; at Addis Abbaba the moderate deficiency of the previous month was repeated.

In Eritrea, a slight excess was recorded at Addi Ugri, in place of a deficiency in May, but throughout the season rainfall in this area did not differ much from the normal.

So far then, the monsoon rains had been weak and below the average; the effect of the early flood waves of February and March was passing off, and though low-stage levels were still favourable, the gauge at Wadi Halfa was falling steadily, and the lowest reading was reached on June 14. On the whole, the rains were rather late and weak in the Sudan area in this month.

Normally in July the rains on the equatorial plateau and on the east coast have greatly diminished from what they were in June, and the summer dry season has set in. In the Bahr el Jebel, Bahr el Ghazal, and Sobat basin rains are heavy, as well as on the Sudan plains. On the Abyssinian tableland the rains are heavy, nearly 30% of the annual rainfall falling in this month.

The amount of rain recorded in regions in and around the Nile basin in July 1906, is given in the following table, No. V and two principal facts come out clearly; firstly, excess of precipitation on the equatorial East Coast, which has been persistent since the beginning of the year, is now replaced by a deficiency; secondly, the rainfall over the Sudan plains has been somewhat above the average at almost all the stations from which information has been received. In Abyssinia there was a marked improvement, the rain at Addis Abbaba being 75 mm. above the average, but this did not extend weastwards to the Sudan, nor northwards into Eritrea, for at Roseires and Addi Ugri it was 38 mm. and 18 mm. below the normal respectively. The general features of July were a steady improvement in the rains, which, however, were not sufficient to bring the river levels up to the average after the late arrival and weakness of the June rains. Few heavy falls seem to have occurred, judging from the gauge curves of Roseires and Khashm el Girba.

In August, rainfall was usually in defect in the equatorial belt except on Lake Victoria, still it is the middle of the dry season here, and the rainfall is of no special significance for the Nile flood. On the Sobat and the Sudan plains, it was almost everywhere above the mean, and appears to have been generally better than for several years past.

In Abyssinia it was considerably above the average at Addis Abbaba but must have decreased rapidly westwards as neither the fall recorded

at Roseires nor the river levels are commensurate with the amount which fell on the eastern crest of the tableland.

In this month the heaviest rain falls on the Abyssinian tableland where no measurements are as yet being made and it is certain that valuable information could be obtained by a competent meteorologist spending a rainy season on the tableland for the purpose of studying the meteorological conditions there, as will be done in 1907.

This year the rain fell in a series of heavy storms at 6 to 8 days' interval which caused a series of flood waves in the Blue Nile. These have been utilized to determine their rate of translation downstream at different stages of the flood.

By the time Khartoum is reached these waves have flattened considerably and the curves only slightly indicate them. Gauge readings at Roseires only exist from 1900, that is during a series of dry years but it seems probable that in years of high flood not only are high gauge readings recorded but the fall betwen successive flood waves is much less than in less favourable years, showing that rain is more continuous.

In September a heavy burst of rain occurred in Abyssinia in the first days of the month after which the rains fell off rapidly both there and in Eritrea. The Addis Abbaba rainfall was 42 mm. below the average and at the stations on the Sudan plains it was rather above the average; at El Obeid an excess of 50 mm. was recorded.

On the Sobat and some places on the Bahr el Jebel the fall was rather deficient but at others as Gondokoro it was above the average, and at Wau in the Bahr el Ghazal the same occurred. The definite decrease of the flood began at Roseires on Sept. 9, at Khartoum on Sept. 12, and at Wadi Halfa on September 17, these being very little after the average dates.

The maximum readings were :—

PLACE.	Date.	Mean date.	Reading.	Mean Reading.	Diff.	No. of years in mean.
			m.	m.	m.	
Roseires	Sept. 1	Aug. 21	21·10	20·21	+0·89	7
Khartoum	„ 14	„ 31	16·51	15·98	+0·53	7
Khashm el Girba.	Aug. 26	„ 21	15·30	14·98	+0·32	4
Berber	Sept. 8	Sep. 2	7·75	7·54	+0·21	7
Wadi Halfa	„ 14	„ 2	8·19	8·16	+0·03	17
Aswan.....	„ 20	„ 4	92·78	93·07	−0·29	38

Both the Wadelai gauge and that on the Albert Lake at Butiaba rose in September with the returning rains, but at Kisumu the Victoria lake continued to fall slowly towards its autumn minimum.

The rainfall near the lake and also on the Coast was slightly below the average.

On the whole therefore it may be said that September rains in the Nile Basin were about normal both in intensity and in the date of their withdrawal.

In October rains were heavy on the Bahr el Jebel and the Bahr el Ghazal, but on the Lake Plateau they were slightly in defect. At Zanzibar there was a fair excess but in East Africa generally the fall was not abnormal.

In November rain was deficient on the Upper Bahr el Jebel and on the Lake Plateau, in East Africa it was on the whole somewhat deficient though a few places had very heavy rain. At Zomba it was above the average.

In December although rain at Zanzibar and Mombasa was excessive, at other places it was usually below the average.

TABLE V (*continued.*)

Monthly Rainfall in Millimetres in 1906.

A.—Stations near but not in the Nile basin.

STATIONS.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	YEAR.
Mauritius	88	130	**283**	4	102	46	143	48	45	52	17	110	1068
Seychelles	**523**	225	311	358	131	114	69	22	24	117	196	343	2433
British Centr. Africa:													
Zomba	218	116	93	18	2	2	3	2	9rops	78	211	**259**	1002
German East Africa:													
Dar-es-Salam	117	153	266	**368**	253	33	16	1	20	28	25	131	1411
Kilossa	14	20	**87**	28	14	19	4	1	7	...	...	...	[194]
Mpapua	...	...	**253**	107	0	...	...	...	...	...	11	142	[513]
Tabora	74	114	**218**	180	0	0	0	0	0	37	41	...	[664]
Ujidji	79	125	**210**	117	1	0	0	0	14	115	52	...	[713]
Tanga	78	130	134	**606**	443	165	84	34	44	43	335	87	2183
British East Africa:													
Zanzibar...	170	106	270	**564**	387	141	17	14	31	139	195	326	2360
Mombasa	28	73	81	**515**	494	265	49	[10]	24	21	99	203	1862
Takaungu	3	56	105	165	**565**	224	91	21	26	36	71	87	1450
Malindi	12	10	33	337	**601**	277	56	24	20	26	102	0	1498
Golbanti...	0	55	145	136	**255**	122	...	...	...	...	...	...	[713]
Kismayu	0	0	7	174	227	**237**	88	5	0	0	11	0	749
Lamu	0	1	82	295	**751**	471	38	51	7	7	49	45	1797
Baringo	0	109	**121**	64	**121**	68	50	29	50	18	24	8	662
Mazeras	30	65	84	400	506	319	210	35	53	0	285	**560**	2547
Shimoni...	39	76	66	427	**463**	235	59	23	65	43	125	84	1705
Makindu { Govt. Farm... ...	2	**122**	Closed after February.										[124]
Makindu { Railway Station..	0	91	132	104	18	0	0	0	0	5	**156**	40	546
Machakos	0	133	248	**414**	36	18	3	44	0	72	141	105	1214
Nairobi { Govt. Farm... ...	48	123	265	**310**	112	40	22	61	9	134	96	42	1262
Nairobi { Railway Station..	45	124	218	**366**	96	43	17	17	5	103	84	...	[1118]
Nairobi { Sub. Comr. House.	54	105	239	**394**	92	36	...	...	...	...	...	...	[920]
Naivasha { Govt. Farm... ...	0	59	199	**246**	131	56	28	33	50	12	44	...	[858]
Naivasha { Railway Station...	0	95	199	**246**	5	0	13	36	144	70	71	8	887
Fort Hall	0	100	237	**308**	73	63	21	21	6	160	135	12	1136
Nakuru...	0	40	**161**	133	91	65	60	73	38	68	46	8	783
Kikuyu	22	170	294	**393**	102	48	20	10	7	52	90	77	1285
Molo	0	161	**278**	220	187	122	134	164	89	70	67	13	1505
Eldama Ravine	0	195	**245**	203	161	147	113	126	42	49	57	26	1364
Athi River	0	121	241	**260**	32	20	7	56	0	93	59	7	896
Kitui	1	54	**344**	325	10	20	6	0	0	71	219	185	1235
Voi	17	98	125	**252**	37	77	8	0	0	0	139	151	904
Mackinnon Road... ...	0	147	130	79	103	105	12	1	17	11	**154**	114	873

TABLE V (*continued*)

Monthly Rainfall in Millimetres in 1906.

B.—Station within the Nile Basin.

STATION.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
German East Africa:					**LAKE PLATEAU BASIN.**								
Muanza	52	165	253	**305**	7	26	0	80	70	84	**112**	...	[1154]
Shirati	19	137	**188**	127	177	43	1	5	15	6	**25**	...	[743]
Bukoba	129	109	287	**306**	114	119	0	66	**156**	...	...	...	[1286]
British East Africa:													
Lumbwa...	0	140	213	174	**295**	167	**304**	151	106	181	25	65	1821
Muhoroni	12	**388**	260	289	339	126	81	**110**	73	58	5	28	1769
Nandi	13	105	254	241	**286**	216	173	**200**	163	147	34	41	1873
Kisumu	5	**395**	329	202	165	156	36	146	53	74	39	**208**	1808
Port Florence	8	**416**	374	163	104	155	40	**145**	64	72	50	210	1801
Mumias	12	208	171	**262**	244	182	35	**184**	164	145	83	78	1768
Kericho	24	255	**280**	244	192	79	89	**237**	95	120	122	68	1805
Uganda:													
Jinja	5	138	**254**	202	90	88	24	**145**	74	120	26	30	1196
Entebbe...	72	126	150	**371**	122	129	42	**153**	64	123	57	117	1526
Lumbuyu Hill	15	...	Closed after January.							...	...	...	[15]
Masaka	10	131	182	**256**	206	156	120	42	**127**	111	55	100	1496
Mbarara...	20	197	318	**332**	151	24	48	145	80	**249**	135	51	1750
Fort Portal (Toru) ...	3	149	**180**	108	53	83	11	121	**297**	218	96	34	1353
Butiaba	23	75	34	146	153	**179**	36	**97**	35	88	54	[42]	962
Masindi	...	...	...	...	...	...	...	...	**100**	86	46	49	281
Bahr el Jebel:					**BAHR EL JEBEL AND BAHR EL GHAZAL BASINS.**								
Wadelai	4	91	133	74	85	[140]	Gauge moved to "Fatiko."					...	[527]
Fatiko	...	...	...	...	...	...	33	250	**338**	186	76	7	[890]
Nimule	0	27	125	48	130	100	[118]	103	**148**	143	47	0	989
Gondokoro	9	70	139	87	137	65	207	196	174	**226**	28	0	1338
Mongalla	3	94	42	74	88	130	**228**	79	53	134	8	1	934
Bor Mission Station ...	...	...	...	...	[72]	**177**	165	73	167	52	0	0	[705]
Bor	0	59	50	36	139	72	172	125	**246**	55	0	0	954
Ghaba Shambe	0	119	17	14	72	52	**204**	177	156	186	0	0	997
Bahr el Ghazal:													
Kafi Kinji	...	...	...	...	...	[118]	214	**222**	168	80	0	0	[802]
Deim Zubeir...	0	0	0	0	32	**249**	167	129	172	126	2	0	877
Meshra er Rek	0	0	0	14	15	156	**166**	159	92	78	0	0	680
Wau	0	62	32	15	87	**173**	87	169	125	110	1	0	861
River Baro:					**SOBAT BASIN.**								
Gambela...	17	37	123	60	148	188	116	**226**	[96]	...	[0]	[0]	1011

TABLE V (*continued*).

Monthly Rainfall in Millimetres in 1906.

B.—STATION WITHIN THE NILE BASIN (*continued*).

STATION.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	YEAR.
River Sobat:													
Nasser (Tawfot 17.11.05).	0	105	11	28	50	86	[20]	Ceased after (July 14th. 1906)					[300]
Abwong	...	...	...	...	[9]	[18]	[93]	...	...	[18]	0	0	[138]
Doleib Hilla	0	72	5	19	49	166	143	139	93	27	4	0	717
Kordofan:						**WHITE NILE BASIN.**							
El Obeid	0	0	0	0	4	127	128	69	110	46	0	0	484
White Nile:													
Attigo	...	...	...	...	...	[147]	104	199	152	93	0	0	[695]
Taufikia	...	...	0	30	48	114	118	117	71	89	12	0	[599]
Kodok	0	10	1	33	66	194	208	175	69	68	28	0	852
Melut	...	...	48	75	32	96	106	76	122	29	0	0	[584]
Renk	...	[2]	0	0	4	120	159	122	125	43	0	0	[475]
Goz Abu Guma	0	0	0	0	24	52	92	69	...	...	...	[0]	[237]
Kawa	0	0	0	2	Heavy	3	26	167	56	50	0	0	304
El Dueim	0	0	30	0	46	40	134	218	83	55	0	0	606
Geteina	0	0	very little	0	0	18	36	46	22	15	0	0	137
Khartoum { Hospital	0	0	0	0	0	4	90	96	24	13	0	0	227
Khartoum { Irrig. Office ...	...	...	...	...	0	5	83	100	28	16	0	0	[232]
Blue Nile:						**BLUE NILE BASIN.**							
Addis Abbaba*	9	156	189	103	60	132	320	358	119	16	28	0	1550
Keili	...	...	...	...	...	...	...	[22]	175	...	...	0	[197]
Roseires	0	0	8	2	34	191	182	222	179	14	2	0	834
Abu Naama etc.	0	0	1	3	0	75	200	455	144	0	0	0	878
Singa	0	0	Light	0	30	120	160	257	85	13	0	0	665
Sennar	0	0	0	0	0	58	158	129	92	46	0	0	483
Wad Medani	0	0	0	0	0	21	131	116	53	61	0	0	382
Mesellemia	0	0	0	0	0	0	52	46	49	0	0	0	147
Managil	0	0	0	0	11	29	58	75	136	54	0	0	363
Rufaa	0	0	0	4	0	4	56	58	83	61	0	0	266
Kamlin	0	0	0	0	0	0	28	12	42	47	0	0	129
Abu Deleig	0	0	0	0	0	8	16	53	80	25	0	0	182
River Atbara:†						**ATBARA AND GASH BASINS.**							
Gallabat	0	10	16	2	27	130	207	245	192	115	0	0	944
Gedaref	0	1	20	0	1	75	170	308	102	22	2	0	701
Khashm el Girba ...	...	...	...	...	...	28	256	166	22	[30]	...	...	[502]
Khor el Gash:‡													
Chenefena	...	...	4	7	1	33	51	53	11	4	110	0	274
Asmara	...	4	4	7	Drops	6	167	114	13	3	15	0	[333]
Addi Ugri	Drops	5	Drops	23	4	74	137	176	34	10	17	0	480
Kassala	0	8	0	0	0	12	78	87	41	50	0	0	280

* Strictly in the Hawash Basin but is not far from the watershed.
† Lower course of Takazze and Settit rivers.
‡ Lower course of River Mareb.

TABLE V (*continued*).

Monthly Rainfall in Millimetres in 1906.

C.—Red Sea Coast.

STATIONS.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November	December.	Year.
Aden	0	**27**	0	0	0	0	0	1	0	0	0	1	29
Massaua	0	**24**	12	4	0	0	0	3	0	2	22	0	67
Ghinda	35	63	31	12	4	0	...	...	0	30	**96**	0	[271]
Suakin	22	2	0	0	0	0	0	0	0	0	**90**	23	137
Port Sudan	< Rainy days See Table VIII >									0	**73**	0	[73]
Erkowit...	**155**	12	0	0	0	1	23	15	4	0	...	...	[210]

D.—Stations in Upper and Lower Egypt.

STATIONS.		January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
Cairo	Helwan	5	1	5	Drops	**10**	0	0	0	0	3	1	2	27
	Giza	2	1	3	Drops	**6**	0	0	0	0	5	1	0	18
	Abbassia	1	1	1	0	5	0	0	0	0	**9**	0	0	17
	Suez	**8**	0	0	0	0	5	0	0	0	0	0	0	13
	Ismailia	6	1	4	0	**41**	0	0	0	0	0	Drops	Drops	52
	Port Said	**24**	6	9	5	6	0	0	0	0	1	Drops	1	52

E.—Stations in Beheira Province and west of the Nile Delta.

STATIONS.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
Mersa Matruh	**11**	6	6	0	0	0	0	0	0	0	0	0	23
Ras el Kanais	55	**95**	10	0	32	0	6	0	0	12	74	4	288
Alexandria	32	43	6	3	9	0	0	0	0	19	**64**	31	207
Mex...	27	28	1	0	13	0	0	0	0	23	**79**	0	171
Kafr Dawar	14	29	6	5	12	0	0	0	0	9	28	**34**	137
Abu Hommos	14	**22**	3	6	8	0	0	0	0	18	19	19	109
Atf	15	23	2	8	3	0	0	0	0	16	**35**	11	113
Damanhur	16	**21**	6	4	16	0	0	0	0	8	12	12	95
Shubrakhit	**24**	20	5	5	12	0	0	0	0	17	13	8	104
Teh el Barud	0	8	6	2	**2**	0	0	0	0	15	**18**	5	56
Kafr Bulin	5	0	6	2	**7**	0	0	0	0	2	5	2	29
Khatatba	3	0	1	0	2	0	0	0	0	**6**	0	0	12
Hosh Issa	0	14	3	6	9	0	0	0	0	**31**	29	1	93

F.—Stations in Daqahlia and Gharbia Provinces (Lower Egypt).

Manzala	...	...	...	...	...	...	...	...	...	[0]	**4**	0	[4]
Mansoura	...	...	...	...	...	...	...	...	...	3	**4**	0	[7]
Ebshan	...	...	...	...	...	...	...	...	...	[**9**]	5	0	[14]
Belqas	...	...	...	...	...	...	...	...	...	5	**14**	0	[19]

TABLE VI.

Difference of Rainfall of 1906 from the Mean in Millimetres.

STATIONS. *	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	YEAR.
Mauritius	— 18	— 62	+ 31	—110	+ 22	— 7	+ 82	— 20	+ 10	+ 20	— 31	— 13	— 96
Seychelles	+ 64	— 83	+ 33	+181	— 25	— 26	+ 7	— 52	—105	— 10	— 92	— 35	—143
Zomba	— 65	—176	—113	— 75	— 16	— 10	— 5	— 1	— 8	+ 34	+ 74	— 19	—380
Dar es Salam	+ 23	+100	+134	+ 56	+ 46	+ 5	— 25	— 28	— 12	— 6	— 55	+ 19	+257
Kilossa	— 83	— 87	— 36	—121	— 38	+ 12	— 15	— 14	— 5	...	...	...	...
Mpapua	...	...	+ 95	+ 35	— 12	...	...	...	...	0	— 16	+ 5	...
Tabora	— 72	— 18	+ 49	+ 47	— 21	— 4	0	0	— 7	+ 25	— 41	...	...
Ujiji	— 29	0	+ 55	— 12	— 31	— 6	0	0	+ 2	+ 74	— 52	...	...
Tanga	+ 32	+ 87	+ 29	+318	+101	+101	— 25	— 45	— 40	— 43	+106	+ 19	+640
Zanzibar	+ 84	+ 71	+105	+300	+117	+114	— 53	— 34	— 21	+ 63	— 41	+256	+961
Mombasa	+ 6	+ 49	+ 13	+329	+143	+164	— 32	— 46	— 29	— 52	— 39	+145	+651
Takaungu	— 7	+ 39	+ 47	+ 32	+187	+118	— 11	— 28	— 23	— 29	— 39	+ 63	+349
Malindi	+ 4	+ 4	+ 8	+173	+240	+147	— 41	— 12	— 19	— 38	+ 3	— 23	+446
Kismayu	— 1	— 1	+ 1	+130	+ 91	+145	+ 39	— 15	— 19	— 4	— 8	— 7	+351
Shimoni	+ 4	+ 54	— 29	+165	+ 63	+106	— 54	— 39	+ 8	— 6	— 28	+ 26	+270
Machakos	— 33	+ 58	+105	+198	— 28	0	— 2	+ 34	— 5	+ 17	— 67	— 13	+264
Nairobi (Govt. Farm)	+ 2	+ 3	+134	+109	— 20	— 14	+ 3	+ 35	— 6	+ 75	— 28	— 50	+243
Fort Hall	— 23	+ 14	+ 85	— 1	— 39	— 3	— 3	— 1	— 15	+ 24	— 52	— 58	— 72
Kikuyu	— 16	+ 81	+126	+150	— 81	— 20	— 6	— 9	— 30	+ 6	— 43	— 17	+141
Eldama Ravine	— 33	+117	+137	+ 74	+ 44	+ 47	+ 33	+ 38	— 18	0	+ 7	— 15	+431
Muanza	— 9	+ 69	+ 74	+ 71	— 65	— 18	— 2	+ 36	+ 26	+ 5	— 14	...	...
Shirati	— 37	+ 74	+ 97	— 19	+ 51	+ 4	— 11	— 3	— 4	— 37	— 30	...	...
Bukoba	+ 22	— 21	+ 70	— 85	—131	+ 73	— 19	+ 10	+ 89	...	...	...	...
Kisumu	— 64	+234	+181	+ 47	+ 51	+ 71	— 9	+ 82	— 20	— 8	— 90	+ 23	+498
Port Florence	— 70	+252	+158	+ 12	— 27	+ 43	— 6	+ 61	— 2	— 18	— 47	— 19	+337
Mumias	— 60	+110	+ 41	+ 41	+ 34	— 8	—122	+ 23	— 6	— 3	— 70	— 21	— 41
Jinja	— 62	+ 67	+126	+ 26	— 29	+ 20	— 26	+ 31	+ 6	+ 8	— 87	— 50	+ 30
Entebbe	— 4	+ 35	— 29	+133	— 45	0	— 26	+ 76	— 17	+ 29	—101	— 28	+ 23
Masaka	— 45	+ 42	+ 48	+ 31	+ 33	+103	+ 74	— 15	+ 8	— 23	— 59	— 26	+171
Mbarara	— 72	+ 86	+ 28	+168	+ 57	— 8	+ 20	+ 17	—105	+ 14	—102	—121	— 18
Fort Portal (Toru)	— 31	+ 68	+ 14	— 22	— 81	— 30	— 71	+ 5	+101	— 8	— 39	— 24	—118
Wadelai	— 20	+ 55	+ 19	— 20	— 34	+ 46	...	...	...	...	...	...	...
Gondokoro	+ 4	+ 51	+ 70	+ 5	— 27	— 35	+ 62	+ 55	+ 22	+ 85	— 15	— 12	+265
Mongalla	0	+ 55	— 9	— 29	— 5	— 8	+117	— 78	— 44	— 6	— 27	— 3	— 37
Ghaba Shambe	0	+ 79	+ 11	— 3	— 4	+ 7	+ 78	+ 51	+ 15	+106	— 6	0	+334
Doleib Hilla	0	+ 48	— 14	— 9	— 28	+ 34	— 9	— 7	— 32	— 42	— 26	0	— 85
El Obeid	0	0	— 4	0	+ 2	+ 77	+ 16	— 33	+ 50	+ 22	0	0	+130
Kodok	0	+ 8	— 1	+ 17	+ 9	+ 56	+ 88	— 32	— 33	— 1	+ 22	0	+133
El Dueim	0	0	+ 24	0	+ 25	+ 26	+ 48	+131	+ 30	+ 40	0	0	+324
Khartoum (Hospital)	0	0	0	0	— 4	— 18	+ 58	+ 54	+ 12	+ 2	0	0	+104
Addis Abbaba	0	+108	+ 84	+ 18	— 18	— 14	+ 75	+ 66	— 42	+ 2	+ 15	— 3	+291
Roseires	0	0	+ 4	+ 1	— 11	+ 50	— 38	+ 25	+ 23	— 10	— 7	0	+ 37
Gallabat	0	+ 7	+ 11	+ 1	— 13	+ 6	+ 12	— 1	+ 37	+ 47	— 4	0	+108
Gedaref	0	+ 1	+ 9	0	— 24	+ 3	— 5	+110	— 4	+ 9	— 10	0	+ 89
Khashm el Girba	...	...	...	...	...	+ 8	+116	+ 46	— 28	+ 8	...	...	...
Wad Medani	0	0	0	0	— 20	— 22	— 4	— 13	— 23	+ 48	— 2	0	— 28
Chenefena	...	...	0	+ 1	— 34	— 3	— 45	— 69	— 19	— 2	+ 55	0	...
Addi Ugri	0	— 1	— 12	+ 1	— 34	+ 7	— 16	— 3	— 3	0	+ 7	— 4	— 58
Kassala	0	+ 7	0	— 1	— 6	— 10	+ 7	— 18	— 23	+ 31	0	0	— 13
Aden	— 11	+ 20	— 15	— 5	— 4	— 3	— 1	— 2	— 3	0	— 3	— 2	— 29
Ghinda	— 32	— 39	— 72	— 12	— 9	— 6	...	...	— 12	— 2	+ 26	— 73	...
Suakin	— 4	— 7	— 1	— 1	— 1	0	— 3	0	0	— 37	+ 2	— 28	— 80
Cairo (Giza)	— 1	— 3	0	— 2	+ 5	0	0	0	0	+ 4	+ 1	— 4	0
Cairo (Abbassia)	— 7	— 4	— 3	— 2	+ 3	0	0	0	0	+ 8	— 4	— 7	— 16
Suez	+ 1	— 3	— 2	— 2	— 1	+ 5	0	0	0	0	— 1	— 4	— 7
Ismailia	— 4	— 5	— 2	— 3	+ 36	0	0	0	0	— 2	— 5	— 11	+ 4
Port Said	+ 3	— 3	— 1	0	+ 5	0	0	0	0	— 1	— 12	— 21	— 30
Alexandria	— 27	+ 12	— 10	0	+ 8	0	0	0	— 2	+ 11	+ 26	— 32	— 14

* Stations having at least 4 years' observations.

TABLE VII.

Difference of Rainfall of 1906 from the Mean as Percentage of the Mean Rainfall.

STATIONS. *	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	YEAR.
Mauritius	— 17	— 32	+ 12	— 96	+ 28	— 13	+134	— 29	+ *29*	+ *62*	— *65*	— 11	— 8
Seychelles	+ 14	— 27	+ 12	+102	— 16	— 19	+ 11	— 70	— 81	— 8	— 32	— 9	— 6
Zomba	— 23	— 60	— 55	— 81	— *89*	— *83*	— *62*	— *33*	—*100*	+ 77	+ 54	— 7	— 28
Dar-es-Salam	+ 24	+189	+102	+ 18	+ 22	+ *18*	— 61	— 97	— *38*	— *18*	— 69	+ 17	+ 22
Kilossa	— 86	— 81	— 29	— 81	— 73	+*171*	— *79*	— *93*	— *42*	...	...	...	...
Mpapua	...	...	+ 60	+ 49	—*100*	...	...	...	...	*0*	— *59*	+ 4	...
Tabora	— 49	— 14	+ 29	+ 35	—*100*	—*100*	*0*	*0*	—*100*	+*208*	— 50	...	...
Ujiji	— 27	0	+ 35	— 9	— *97*	—*100*	*0*	*0*	+ *17*	+*180*	— 50	...	...
Tanga	+ *70*	+*202*	+ 28	+110	+ 30	+158	— 23	— 57	— 48	— 50	+ 46	+ 28	+ 41
Zanzibar	+ 98	+*203*	+ 64	+114	+ 43	+*422*	— 76	— *71*	— 40	+ 83	— 17	+366	+ 69
Mombasa	+ *27*	+*204*	+ 19	+177	+ 41	+162	— 40	— 82	— 55	— 71	— 28	+250	+ 54
Takaungu	— *70*	+*229*	+ 81	+ 24	+ 49	+111	— 11	— *57*	— *47*	— 45	— 35	+*262*	+ 32
Malindi	+ *50*	+ *67*	+ *32*	+105	+ 66	+113	— 42	— *33*	— *49*	— *59*	+ 3	—*100*	+ 42
Kismayu	—*100*	—*100*	+ *17*	+*295*	+ 67	+158	+ *80*	— 75	—*100*	—*100*	— *42*	—*100*	+ 88
Shimoni	+ *11*	+*245*	— 31	+ 63	+ 16	+ 82	— 48	— 63	+ 14	— *12*	— 18	+ 45	+ 19
Machakos	—*100*	+ 77	+ 73	+ 92	— 44	*0*	— *40*	+*340*	—*100*	+ 31	— 32	— 11	+ 28
Nairobi (Govt. Farm).	+ *4*	+ 2	+102	+ 54	— 15	— 26	+ *16*	+*135*	+ *49*	+127	— 23	— 54	+ 24
Fort Hall	—*100*	+ 16	+ 56	0	— 35	— 5	— *12*	— 5	— 71	+ 18	— 28	— 83	— 6
Kikuyu	— *42*	+ 91	+ 75	+ 62	— 44	— 29	— *23*	— *47*	— *81*	+ *13*	— 32	— 18	+ 12
Eldama Ravine ...	—*100*	+150	+127	+ 57	+ 38	+ 47	+ 41	+ 43	— 30	*0*	+ *14*	— 37	+ 46
Muanza	— 15	+ 72	+ 41	+ 30	— 90	— *41*	—*100*	+ *82*	+ *59*	+ 6	— 11	...	...
Shirati	— 66	+117	+107	— 13	+ 40	+ *10*	— *92*	— *38*	— *21*	— *86*	— 55	...	...
Bukoba	+ 21	— 16	+ 32	— 22	— 53	+*159*	—*100*	+ 18	+133	...	...	...	...
Kisumu	— 93	+145	+122	+ 30	+ 45	+ 84	— *20*	+128	— 27	+ 10	— 70	+ 12	+ 38
Port Florence	— 90	+154	+ 73	+ 8	— 21	+ 38	— *13*	+ 73	— 3	— 20	— 48	— 8	+ 23
Mumias	— 83	+112	+ 32	+ 19	+ 16	— 4	— 78	+ 14	— 4	— 2	— 46	— 21	— 2
Jinja	— 93	+ 94	+ 98	+ 15	— 24	+ 29	— *52*	+ 27	+ 9	+ 7	— 77	— 62	+ 3
Entebbe	— 5	+ 38	— 16	+ 56	— 27	0	— 38	+ 99	— 21	+ 31	— 64	— 19	— 2
Masaka	— 82	+ 47	+ 36	+ 14	+ 19	+194	+*161*	— 26	+ 7	— 17	— 52	— 21	+ 13
Mbarara	— 78	+ 77	+ 10	+102	+ 61	— *25*	+ *71*	+ 13	— 57	+ 6	— 43	— 70	— 1
Fort Portal (Toru) ...	— *91*	+ 84	+ 8	— 17	— 60	— 27	— 87	+ 4	+ 52	— 4	— 29	— 41	— 8
Wadelai	— *83*	+*153*	+ 17	— 21	— 29	+ 49	...	...	...	...	...	...	...
Gondokoro	+ *80*	+*268*	+101	+ 6	— 16	— 35	+ 43	+ 39	+ 14	+ 60	— *35*	—*100*	+ 25
Mongalla	*0*	+*141*	— 18	— 28	— 5	— 6	+105	— 50	— 45	— 4	— 77	— *75*	— 4
Ghaba Sambe	*0*	+*198*	+*183*	— *18*	— 5	+ *16*	+ 62	+ 40	+ 11	+132	—*100*	*0*	— 50
Doleib Hilla	*0*	+*200*	— *74*	— *32*	— 36	+ 26	— 6	— 5	— 26	— 61	— *87*	*0*	— 11
El Obeid	*0*	*0*	—*100*	*0*	+*100*	+*154*	+ 14	— 32	+ 83	+ *92*	*0*	*0*	+ 37
Kodok	*0*	+*400*	— *50*	+*106*	+ 16	+ 41	+ 73	— 15	— 32	— 1	+*367*	*0*	+ 18
El Dueim	*0*	*0*	+*400*	*0*	+*119*	+*186*	+ 56	+151	+ 57	+*267*	*0*	*0*	+ 115
Khartoum (Hospital).	*0*	*0*	*0*	*0*	—*100*	— *82*	+*181*	+*129*	+*100*	+ *18*	*0*	*0*	+ 85
Addis Abbaba	*0*	+*225*	+ 80	+ 21	— 23	— 10	+ 25	+ 23	— 26	+ *14*	+*115*	—*100*	+ 23
Roseires	*0*	*0*	+*100*	+*100*	— *24*	+ 35	— 17	+ 13	+ 15	— *42*	— *78*	*0*	+ 5
Gallabat	*0*	+*233*	+*220*	+*100*	— *32*	+ 5	+ 6	— 0	+ 24	+ 69	—*100*	*0*	+ 12
Gedaref	*0*	Excess	+ *82*	*0*	— *96*	+ 4	— 3	+ 56	— 4	+ *69*	— *83*	*0*	+ 15
Khashm el Girba ...	...	...	...	...	...	+ *40*	+ 83	+ 38	— *56*	+ *36*	...	...	...
Wad Medani	*0*	*0*	*0*	*0*	—*100*	— *51*	+ 3	— 10	— 30	+*369*	—*100*	*0*	— 7
Chenefena	...	...	*0*	+ *17*	— *97*	— *8*	— 47	— 57	— *63*	— *33*	+100	*0*	...
Addi Ugri	*0*	— *17*	—*100*	+ *5*	— *89*	+ 10	— 10	— 2	— *8*	*0*	+ *70*	—*100*	— 11
Kassala	*0*	+*700*	*0*	—*100*	—*100*	— *45*	+ 10	— 17	— 36	+*135*	*0*	*0*	— 4
Aden	—*100*	+*286*	—*100*	—*100*	—*100*	—*100*	—*100*	— 67	—*100*	*0*	—*100*	— *67*	— 50
Ghinda	— 48	— 38	— 70	— *50*	— *69*	—*100*	...	...	—*100*	— *6*	+ 36	—100	...
Suakin	— *15*	— *78*	—*100*	—*100*	—*100*	*0*	—*100*	*0*	*0*	—*100*	+ 2	— 55	— 37
Cairo { Giza ...	— *33*	— *75*	*0*	—*100*	+*500*	*0*	*0*	*0*	*0*	+*400*	Excess	—*100*	*0*
Cairo { Abbassia ...	— *88*	— *80*	— *75*	—*100*	+*150*	· *0*	*0*	*0*	*0*	+*800*	—*100*	—*100*	— *48*
Suez	+ *14*	—*100*	—*100*	—*100*	—*100*	Excess	*0*	*0*	*0*	*0*	—*100*	—*100*	— *35*
Ismailia	— *40*	— *83*	— *33*	—*100*	+*720*	*0*	*0*	*0*	*0*	—*100*	—*100*	—*100*	+ *8*
Port Said	+ *14*	— *33*	— *10*	*0*	+*500*	*0*	*0*	*0*	*0*	— *50*	—*100*	— *95*	— 37
Alexandria	— 46	+ *39*	— *62*	*0*	+*800*	*0*	*0*	*0*	—*100*	+*138*	+ *68*	— 51	— 6

* Stations having at least years' observations.

NOTE.—Numbers in italics refer to months in which the average rainfall is 50 mm. or less.

TABLE VIII.

Total Rainy Days in 1906.

	STATIONS.	Jan.			Feb.			March.			April.			May.			June.			July.			Aug.			Sept.			Oct.			Nov.			Dec.			YEAR.		
		A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Bahr el Ghazal.	Tonj	0	0	0	4	0	1	0	1	1	1	0	4	3	2	4	3	5	3	2	2	2	5	2	2	1	2	4	1	6	2	0	2	0	...	...	...	...	...	...
	Rumbek	0	0	0	3	2	4	1	0	1	4	0	1	3	3	5	2	3	8	1	3	13	1	7	5	3	3	2	5	2	2	1	1	0	0	0	0	24	24	41
	Deim Zubeir	0	0	0	0	0	3	0	0	0	0	0	0	(See Table V.)																								...	...	...
	Chak Chak	(No records kept).									0	0	2	4	3	3	6	3	6	4	8	9	1	8	11	3	4	7	3	4	3	0	0	0	0	0	0	[21	30	41]
	Temboura	2	0	0	7	5	0	3	0	1	7	1	1	13	1	0	10	0	1	12	5	5	7	2	7	...	...	...	2	2	6	[3	0	0]	...	...	...	...	...	...
	Meshra er Rek	0	0	0	0	0	0	(See Table V.)																														...	...	...
	Meriddi	[0	1	0]	6	7	2	4	1	2	10	3	4	7	2	12	3	8	4	3	5	9	12	4	5	12	2	4	2	2	15	4	2	1	0	0	0	63	37	58
	M'volo	1	0	0	2	4	4	0	0	6	1	0	3	1	5	5	0	3	6	5	6	5	1	3	12	2	1	13	0	0	9	1	0	0	0	0	0	14	22	63
	Yambio	...	...	...	4	4	4	2	6	3	10	1	8	6	4	9	2	5	7	8	6	3	4	3	8	4	6	6	6	4	9	2	2	6	...	...	...	...	...	...
Kordofan.	Taludi	0	0	0	1	0	0	1	0	1	0	0	0	[1	1	1]	...	...	...	0	3	7	6	3	4	2	4	3	6	2	3	...	...	...	...	...	...	...	...	...
	Delling	0	0	0	0	0	0	0	0	0	1	0	0	4	0	0	6	5	2	6	1	7	1	2	10	0	3	6	2	4	5	...	...	...	...	...	...	...	...	...
	El Adaiya	0	0	0	0	0	0	0	0	0	0	0	0	3	0	2	1	1	5	0	1	5	2	8	8	3	2	5	1	4	2	...	...	...	...	...	...	...	...	...
	Gedid (Dar Gimme)	0	0	0	0	0	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	Khursi	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	2	0	3	1	2	5	0	2	8	1	3	1	0	0	3	...	...	...	...	...	...	...	...	...
	Nahud	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	3	1	2	4	3	5	3	2	6	0	0	3	1	1	...	...	...	[0	0	0]	...	...	...
	Sherkeila	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	3	2	3	4	0	3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	Taiera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	6	3	3	3	1	5	8	1	0	4	1	1	6	...	...	...	...	...	...	...	...	...
	Bara	0	0	0	0	0	0	0	0	0	0	0	0	...	...	...	...	...	...	1	0	4	0	0	1	...	...	...	0	0	1	...	...	...	[0	0	0]	...	...	...
Blue Nile.	Khartoum North	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	[2	0	0	2	0	3]	4	0	4	[0	1	1]	...	...	...	...	...	...	...	...	...	...	...	...
	Omdurman	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	3	2	3	1	4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	Geili	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3	0	4	2	2	0	...	...	...	...	...	...	...	...	...	...	...	...
	Dinder	0	0	0	0	0	0	1	0	0	1	0	0	8	1	0	8	1	5	10	0	6	9	3	7	5	3	1	0	0	1	[0	0	0]	...	...	...	...	...	...
	Dar Fung	0	0	0	0	0	0	0	0	0	0	3	0	[2	1	0]	0	0	0	6	4	3	5	7	3	6	7	0	4	2	0	1	0	0	0	0	0	24	24	6
	Mafaza	0	0	0	0	0	0	[0	0	0]	2	1	0	1	0	1	1	2	6	[0	0	9]	2	1	9	[1	2	1]	...	...	...	...	...	...	...	...	...	...	...	...
Nile Below Khartoum	Shendi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	1	1	4	4	2	2	3	2	1	1	3	0	...	...	...	...	...	...	...	...	...
	Damer	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	1	0	2	1	1	0	1	0	0	0	...	...	...	...	...	...	...	...	...
	Berber	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	0	0	1	0	0	0	0	...	...	...	...	...	...	...	...	...
	Abu Hamad	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	...	...	...	...	...	...	...	...	...
	Dongola	0	0	0	0	0	0	0	0	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Red Sea.	Tokar	4	3	0	0	0	0	2	1	0	1	0	0	1	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	1	0	3	2	0	1	2	0	14	10	0
	Mohamed Ghul	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	3	1	0	0	2	0	3
	Halayib	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	1	0	6	1	0
	Karora	7	0	1	3	0	0	3	1	0	0	0	0	0	0	0	0	0	0	2	0	0	1	0	2	0	0	0	0	1	9	0	1	0	16	3	12			
	Akik	6	0	4	2	0	1	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2	0	6	3	0	0	21	0	11
	Port Sudan	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	...	...	...	...	...	...	...	...	...	...	...	...	(See Table V.)									...	...	...

A.—Total number of days on which rain was light.
B.— " " " " moderate.
C.— " " " " heavy.

CHAPTER IV.

The Nile Flood of 1906.

For seven years past the annual flood has been persistently below the average, so that the occurrence of even the moderate improvement of this year is of special interest; the existence of numerous gauges on the Blue Nile makes its study of additional value, and enables us to follow its development with greater accuracy than hitherto, since nearly all of them have now been connected by levelling as already mentioned.

In discussing the rise and fall of the river flood, we meet with the same difficulty as has been pointed out when dealing with the rainfall of the Nile Basin; namely, that there is a considerable difference in the dates of the lowest and of the highest waterlevel in different parts of river system. The water brought down by a tributary affects that of the channel which it joins, and in this way flood-waves in the upper part of the system may die out, or may pass on after more or less modification.

It is difficult, therefore, to present clearly the development of the flood, as the passage of the water from the catchment basins to the lower reaches of the river is at first slow, then it becomes rapid, and after reaching the maximum gradually decreases; still, in May low stage conditions predominate on the whole, June sees the first rise, which becomes rapid from July 1 to August 15, while the next 30 days include the top of the flood, except in the Sobat and the more southerly tributaries, where the rains extend into September and October as they are withdrawing from Abyssinia and the Sudan plains.

The low stage.—At the end of October 1905, there was every prospect of a very insufficient summer supply in the Nile, since the summer rains of Abyssinia had been weak and ill-sustained; but heavy rainstorms over Abyssinia in November improved matters considerably.

Difference from Mean Gauge Reading in metres.

November, 1905.	1-5	6-10	11-15	16-20	21-25	26-30
Roseires	−0·34	−0·06	+0·11	+0·16	+0·23	+0·39
Khartoum	−0·32	−0·21	−0·11	−0·02	+0·02	0·00
Wadi Halfa	−1·36	−1·15	−1·08	−1·01	−0·98	−0·88
December, 1905.	**1-5**	**6-10**	**11-15**	**16-20**	**21-25**	**26-31**
Roseires	+0·42	+0·38	+0·33	+0·33	+0·25	+0·24
Khartoum	+0·05	+0·09	+0·13	+0·08	+0·04	+0·06
Wadi Halfa	−0·75	−0·74	−0·71	−0·62	−0·58	−0·59

It will be seen from the above table that at the end of 1905 the river levels were below the average, but not excessively so. In February, and again in March, the cyclonic depressions which passed over the Sudan and Abyssinia causing heavy rainfall, as already mentioned, raised the river levels everywhere and converted a moderate deficiency into a well-marked excess, which lasted long enough to provide easy conditions of supply during the early summer months.

The amount of rain which fell in February must have been very large judging from the marked effect which it had on all the rivers in these areas.

The Blue Nile rose 68 cm. at Roseires and 33 cm. at Khartoum; the Sobat rose 50 cm. at Tawfot (Nasser) and 32 cm. at Doleib Hilla. The Bahr el Jebel rose 19 cm. at Mongalla but the rise was hardly felt at Bor and at Ghaba Shambe the level increased by 3 cm.

On the Bahr el Jebel the level fell steadily from the beginning of the month until the 16th when the rainstorm passed over this region and raised the river level by 30 cm. between then and the 22nd at Mongalla.

This rise was as usual imperceptible at Bor 134 kilometres further down-stream, but at Ghaba Shambe, 197 kilometres more to the north, rain must have fallen on the Bahr el Zaraf marshes as a slight rise took place.

On the Sobat a slight rise is shown by the gauges at both Tawfot (Nasser) and Doleib Hilla about the middle of the month.

On the Blue Nile the water level at Roseires rose from 11·53 metres on the 11th Feb. to 12·33 metres on the 25th Feb. and 12·64 metres on the 29th March after which it fell. This rise markedly affected all the Blue Nile gauges, and produced a total rise of 0·19 metres at Khartoum during the first week of April; this coming soon after the February rise which reached Khartoum on March 1-10 has checked the normal fall of the river and has furnished a very considerable volume of water, so that the very low summer levels which were to be anticipated from the poor flood and moderate September and October rains of 1905, were replaced by fairly good ones as a result of (1) the heavy rains at the end of November, (2) those of February and (3) those of March; a wholly unexpected result produced by meteorological conditions which occur occasionally.

The effect will be seen from the following tables in which the differences from the mean gauge-readings are given in metres.

ROSEIRES.

DATE.	February.	March.	April.
	m.	m.	m.
1- 5	+0·57	+1·27	+1·37
6-10	+0·57	+1·01	+1·10
11-15	+0·66	+0·84	+0·98
16-20	+0·84	+0·96	+0·69
21-25	+1·28	+1·33	+0·63
26-30	+1·58	+1·78	+1·11

KHARTOUM.

DATE.	March.	April.	May.
	m.	m.	m.
1- 5	+0·31	+0·58	+0·30
6-10	+0·50	+0·76	+0·33
11-15	+0·55	+0·60	+0·27
16-20	+0·50	+0·52	+0·17
21-25	+0·45	+0·37	+0·09
26-30	+0·52	+0·31	−0·18

WADI HALFA.

DATE.	March.	April.	May.
	m.	m.	m.
1- 5	−0·55	−0·25	−0·06
6-10	−0·55	−0·29	−0·12
11-15	−0·56	−0·25	−0·10
16-20	−0·48	−0·20	−0·26
21-25	−0·37	−0·07	−0·22
26-30	−0·24	+0·03	−0·21

On May 1st the Blue Nile at Roseires stood at 1·13 metres above its average level as deduced from readings in 1900-1905, while at Wadi Halfa the level was 0·01 metre below the mean of 1890-1905. This high level was solely due to these exceptional rainstorms, since the monsoon rains from the south had not yet affected the Sobat river which continued to fall slowly up to May 1 at Doleib Hilla, although usually slight rises are caused in April by the first rains on the Abyssinian tableland.

The early and abnormal rains of February and March raised the level of the Blue Nile considerably and thus converted what would have been a very low summer supply into a fairly good one. On the Bahr el Jebel at Gondokoro and Mongalla, the effect was to raise the level for the last 10 days of February and of March up to that of the beginning of January, and to maintain this level throughout April and May until the heavy rains commenced in June. On the Sobat, the river rose in February and again in March, and maxima were recorded on the following dates, (see Plate V).

Place.	Date of maximum.	Distance in km.	Rate of wave crest per day.	Gambela to Doleib Hilla.
			km.	days.
Gambela	16 February ...	...	...	...
Tawfot	26 „ ...	260	26	19
Doleib Hilla	5 March... ...	244	35	...
Gambela	24 March... ...	...	...	...
Tawfot	28 „	260	65	9
Doleib Hilla	2 April	244	49	...

On the Jur River at Wau these early rises were very marked (Plate VI) but did not affect the Bahr el Ghazal at Meshra el Rek. On the Blue Nile we have (Plate VII) the same two rises in February and March together with another at the end of April at Roseires, after each of which the river level sank below its former level showing that the monsoon rains had not yet set in. The April rainfall did not affect the Sobat basin (Plate V). The flood waves due to these rainstorms are traceable as far as Wadi Halfa on the gauge curves (Plate VIII) and the dates of the arrival of the wave crest at different places are given in the following table. To these are added the rates of movement of other flood waves during the period of flood for comparison. As gauge readings are taken at 8 a.m. only, it is not possible to fix the time of their arrival at any point with precision, and consequently as soon as the velocity increases with the rising flood, the rate of movement of the wave deduced from gauge-readings at neighbouring stations is quite uncertain, and only that which is derived from long distances can be in any degree reliable. The time taken by such flood waves to pass from Roseires to Wadi Halfa, a distance of about 2,170 kilometres, in which the river falls about

325 metres, varies therefore from 30 days when the river is low, to 9 days just before the highest level of the year is reached, corresponding to mean velocities of 72 and 240 kilometres per day or 3 and 10 kilometres per hour respectively ; when that level is attained, the velocity decreases somewhat and the wave which produced the highest flood readings took 12 days to traverse the distance.

TABLE IX.

Place.	Date of maximum.	Distance in km.	Rate of movement of crest per day.		Roseires to Wadi Halfa.
			km.		days.
Roseires	25 February ...	...	...		
Sennar	3 March	287	48		
Wad Medani	5 „	146	73	53	
Khartoum	9 „	206	52		30
Berber	13 „	365	92		
Wadi Halfa	27 „	1,165	79	85	
Roseires	28 March	...	...		
Sennar	1 April	287	72		
Wad Medani	4 „	146	49	71	
Khartoum	6 „	206	103		27
Berber	12 „	365	61		
Wadi Halfa	24 „	1,165	97	85	
Roseires	28 April	...	...		
Sennar	2 May	287	72		
Wad Medani	4 „	146	73	71	
Khartoum	7 „	206	69		25
Berber	11 „	365	91		
Wadi Halfa	23 „	1,165	97	96	
Roseires	15 June	...	...		
Sennar	18 „	287	96		
Wad Medani	20 „	146	73	80	
Khartoum	23 „	206	69		24
Berber	27 „	365	91		
Wadi Halfa	9 July	1,165	97	96	
Roseires	8 July	...	...		
Sennar	10 „	287	144		
Wad Medani	11 „	146	146	128	
Khartoum	13 „	206	103		19
Berber	17 „	365	91		
Wadi Halfa	27 „	1,165	116	109	

TABLE IX (*continued*).

Place.	Date of maximum.	Distance in km.	Rate of movement of crest per day.		Roseires to Wadi Halfa.
			km.		days.
Roseires	31 July	...	...		
Sennar	1 August ...	287	287		
Wad Medani	2 „ ...	146	146	160	
Khartoum	4 „ ...	206	103		13
Berber	5 „ ...	365	365		
Wadi Halfa	12 „ ...	1,165	192	219	
Roseires	8 August ...	...	...		
Sennar	9 „ ...	287	287		
Wad Medani	10 „ ...	146	146	160	
Khartoum	12 „ ...	206	103		10
Berber	14 „ ...	365	182		
Wadi Halfa	18 „ ...	1,165	291	255	
Roseires	16 August ...	...	...		
Sennar	17 „ ...	287	287		
Wad Medani	18 „ ...	146	146	212	
Khartoum	19 „ ...	206	206		10
Berber	21 „ ...	365	182		
Wadi Halfa	26 „ ...	1,165	233	204	
Roseires	22 August ...	...	...		
Sennar	23 „ ...	287	287		
Wad Medani	24 „ ...	146	146	212	
Khartoum	25 „ ...	206	206		9
Berber	27 „ ...	365	182		
Wadi Halfa	31 „ ...	1,165	291	255	
Roseires	31 August ...	...	...		
Sennar	1 Sept.	287	287		
Wad Medani	2 „	146	146	212	
Khartoum	3 „	206	206		13
Berber	5 „	365	182		
Wadi Halfa	13 „	1,165	169	170	

These rates agree well with those deduced from observations on the flood of 1902,* and of 1903.†

The level of Lake Victoria was about the average of the last 10 years at the end of 1905, in which year neither the spring nor the autumn rains had been heavy enough to prevent the lake level from falling from the comparatively high level of May 1904. Still in November an improvement began, which was continued with but a slight check in

* "Report of Public Works Ministry" Egypt, 1902, Cairo, 1903, p. 184.

† "Geog. Jour." 1905, Sept., p. 270.

January 1906 until May and June. The exceptionally heavy rainfall of April and May which fell on the lake plate this year caused a higher level than has been attained of late years, as shown in the following table, while the curves plotted from the daily gauge readings are given in Plate III.

A few years ago this high lake-level would have been understood to involving high flood levels in the Nile, but we now know that Lake Choga and the low-lying marsh area to the north of Lake Victoria reduces the rise of the Victoria Nile between Mruli and Foweira to within very small limits. This year the level at Mruli only rose 0·5 metre between January and the middle of April in spite of the exceptionally heavy rainfall, an amount less than the rise of the lake itself in the same period.

TABLE X.—Victoria Lake Level readings at Kisumuen.

	Mean.*	Maximum.*	Minimum.*	Mean Level * January.	Change.†
	m.	m.	m.	m.	mm
1896	0·928	1·14	0·67	1·10	
1897	... ‡	... ‡	... ‡	0·86	—240
1898	... ‡	... ‡	... ‡	...	...
1899	0·733	1·09	0·30	0·95	+ 90 §
1900	0·391	0·67	—0·02	0·45	—500
1901	0·508	1·05	0·16	0·32	—130
1902	0·172	0·44	—0·02	0·18	—140
1903	0·742	1·05	0·24	0·37	+190
1904	0·917	1·38	0·66	0·85	+480
1905	0·696	1·00	0·39	0·73	—120
1906	1·074	1·43	0·57	0·72	— 10

Bahr el Jebel and Bahr el Ghazal basins.—Since the marshy valleys of these rivers in their lower reaches take up all the extra water which is brought down from the moonson rainfall May-October in their higher reaches, the effective discharge, upstream of the Sobat, only varies within narrow limits throughout the year, and consequently their discharge plays no part in the flood phenomena of the Nile. It will be therefore more convenient to notice their whole cycle of flood range here than to return to it when describing the flood of the main river later.

* These values differ by 65 cm. from the values communicated to Irrigation offices in Egypt since for these latter the lake level at Kisumu Dec. 31st. 1903 was taken to be 1·50. m.

† *i. e.* difference between mean level in January of each year.

‡ Incomplete.

§ From January 1897 to January 1899.

The level of the Bahr el Jebel at Gondokoro and Mongalla remained almost steady during April and May after the improvement caused by the storms of February and March. The heavy rains set in early in June, and occasioned three marked rises, one during the end of June and the first half of July, one early in August, and a third, the most marked, which began in the latter part of August and lasted for a month. The Ghaba Shambe gauge shows signs of a similar variation of the rainfall having reached as far as that place, although at Bor, 134 kilometres north of Mongalla, hardly any variation of level is to be recognized.

The gauge readings at Wadelai were irregular in February and March, but after that date they agree well with those of Butiaba on the Albert Lake, which rose steadily from a minimum in March to a maximum in December, the total range being 0·64 metre. This year, gauge readings are available from Wau on the Jur River 255 kilometres above its junction with the Bahr el Ghazal and 295 from Meshra el Rek itself, which are most instructive. Besides the three early storms in February, March and May, of which the first two are probably unusual, the heavy rains set in about the third week in June, and continued until October. The same three groups of rises in July, August and September are shown (Plate V) as occur on the Bahr el Jebel together with another in October.

The first rise.—On the Sobat the level began to rise at Gambela and at Tawfot in the last few days of April, and at Doleib Hilla on May 6 after which dates the river rose steadily throughout the month.

On the White Nile the level rose slightly in the early days of the month at Taufikia, and from May 29th at Geteina, in consequence of the flood of the Sobat arriving. This wave which caused the first rise took 18 days to travel from Taufikia to Geteina along the wide shallow bed of the White Nile where the slope is extremely low.

On the Blue Nile a temporary rise of 0·6 metre occurred at Roseires in the last 10 days of April, but this only caused a temporary rise of the river at Khartoum, and did not check the regular fall. The true rise commenced at Roseires on May 15, at Khartoum on May 27, and at Wadi Halfa on June 13, these dates were respectively 13, 16, and 9 days later than the average.

The Sobat and the White Nile rose normally and call for no special mention.

In June the rise proceeded regularly on the Blue Nile, one marked wave at Roseires on the 15th affecting the gauges as far as Wadi Halfa.

The rapid rise.—The Sobat reached a first maximum at Gambela on July 22, after which it fell about half a metre, rising for a day to its original level on August 15 and again falling. These changes had, however, no effect on the level at Doleib Hilla, which rose steadily and continuously. Readings at Tawfot near Nasser ceased on July 15 while the river was still rising.

The increased number of gauges on the White Nile this year enable the holding up of its water by the Blue Nile flood to be well seen, and on three of them it is recorded:—

Place.	Dates of Blue Nile effect		Distance from Khartoum in kilom.
	from	to	
Geteina	July 6... ...	November 10	96
Duein	July 10... ...	„ 14	200
Goz Abu Guma...	July 18... ...	*	320

Renk, 175 kilometres higher upstream, was not affected.

There is no doubt that rise of the water level at Meshra er Rek is mainly due to a similar effect of the Sobat flood on the long reach of feeble slope from this point to Taufikia. It will be seen on Plate V that the Meshra er Rek gauge curve shows no sign of the successive flood waves at Wau 255 kilometres upstream on the Jur which joins the Bahr el Ghazal 40 kilometres below Meshra er Rek; the level here rises parallel to the Taufikia gauge curve.

The Blue Nile at Roseires rose 5 metres during July very regularly, and without any marked fluctuation; the level was slightly above that of the last 6 years. At Khartoum the level reached the mean of the same period on July 9, and afterwards kept slightly above it until August 8, when it again touched it.

In August the level at Roseires fluctuated as successive flood waves of from 1·5 to 2 metres range passed down, but at Khartoum these had flattened out about 0·2 or 0·3 metre and the level was just above the mean of 1900-1905.

The Atbara at Khashm el Girba rose markedly at the end of July and the early part of August, so that at Wadi Halfa the level reached the mean of the 15 years 1890-1904 in August, but did not exceed it until the end of the month.

* Observations not reliable.

The general level of the Nile at the principal stations is given in the following table :—

5—Day differences from mean (in metres).

July, 1906	1-5	6-10	11-15	16-20	21-25	26-31	Aug. 1-5	6-10	11-15
Taufikia	—0·14	—0·16	—0·21	—0·26	—0·25	—0·27	—0·27	—0·28	—0·29
Roseires	+0·39	+0·79	+0·48	+0·31	+0·65	+1·23	+0·74	+0·52	+0·21
Khartoum	—0·47	—0·17	+0·30	+0·27	+0·16	+0 20	+0·47	+0·14	+0·20
Khashm el Girba	—0·10	+0·38	—0·13	—0·35	+0·08	+0·38	+0·07	+0·64	+0·53
Berber	—0·49	—0·51	+0·05	+0·23	+0·16	+0·26	+0·61	+0·36	+0·38
Wadi Halfa	—0·71	—0·78	—0·90	—1·07	—0·63	—0·72	—0·74	—0·38	—0·18

At this time of year, so far as present knowledge goes, meteorological data from the Nile Valley and from the equatorial region afford little information as to the conditions on the Abyssinian tableland, while from this region itself data are most meagre. We are therefore compelled to compare the river stage with that of past years.

From these we see that the level at Aswan was below the average 1-5 August in 18 years, but in only three of these (1891, 1893, 1898) was the flood up to or above the average. In 10 years the level remained below the average till 6-10 August and in all these the flood was below the average.

The critical period may be said to be the first 10 days of August, as the volume of the flood depends on the level attained by the Blue Nile at say, Roseires, being maintained for sufficient time in August. In 1903 the river on August 12 rose to a gauge reading of 20·8 metres and then fell slowly throughout the month. In 1904 it rose to 20·5 metres on July 31, then fell abruptly, 18·5 metres being mean for August in that year.

On the ground of this and other information the prediction was made at the beginning of August that the flood would be near the average, and that no grounds existed for expecting that it would exceed it to any extent.

The general character of this period of six weeks 1 July-15 August was that the supply, which was below the average at first, improved rapidly towards the end.

The top of the flood.—August 15-September 15.—Four rises at Roseires with intervening falls took place during this period, and in the third the highest level of the year, 21·10 metres, or 10·05 metres above the lowest reading of 11·05 metres was reached.

At Khartoum a series of small oscillations of 0·25 to 0·50 metre led up to the maximum of 16·51 metres on September 14, ten days

after the average date. The oscillations seen in the Khartoum gauge curve are apparently flattened out before the flood-waves reach Berber, as there each rise and fall can be identified with those of the Khashm el Girba gauge on the Atbara River.

The Atbara rose twice markedly in this period, and reached its highest level at Khashm el Girba on August 26, that of Berber on the 28th corresponding to it, but this was exceeded by the readings of September 8 and 11 to 14, due to a flood-wave from Khartoum.

The water-level at Wadi Halfa first exceeded the mean of 15 years on the 10th, 18th and 29th of August and again on September 9, while the highest reading of the year, 8·19 metres or 0·03 metre above the mean maximum, was recorded on September 14.

On comparing the Wadi Halfa gauge curve for 1906 with the mean curve 1890–1905, the flood will be seen to have been on the whole slightly below the average, but a rapid increase in the Abyssinian rainfall at the end of August caused the highest reading to exceed the mean.

The fall of the flood.—After September 9 the Blue Nile fell rapidly at Roseires though four or five small flood-waves slightly checked it, and the level remained just above the mean of the last 5 years. At Khartoum the same took place, while the water-level at Wadi Halfa reached the mean value of the last 16 years on October 5 and fell below it on October 27. In November the fall was very rapid and during the second half of the month the level was 0·80 below the average, but a flood wave in this month checked the fall and caused but a moderate defect in December.

5. DAY DIFFERENCES FROM THE MEAN IN METRES.

October, 1906	1-5	6-10	11-15	16-20	21-25	26-31
Wadi Halfa	+0·22	−0·10	−0.12	−0·05	−0·14	−0·24
Khartoum	+0·49	+0·74	+0·84	+0·64	+0·52	+0·42
Roseires	+0·96	+1·08	+0·52	+0·24	+0·41	+0·29
November, 1906	**1-5**	**6-10**	**11-15**	**16-20**	**21-25**	**26-30**
Wadi Halfa	−0·39	−0·95	−0·99	−1·03	−0·98	−0·89
Khartoum	+0·33	+0·28	+0·26	+0·34	+0·39	+0·33
Roseires	+·022	+0·19	+0·42	+0·64	+0·52	+0·38
December, 1906	**1-5**	**6-10**	**11-15**	**16-20**	**21-25**	**26-31**
Wadi Halfa	−0·76	−0·66	−0·59	−0·49	−0·43	−0·38
Khartoum	+0·29	+0·31	+0·28	+0·26	+0·28	+0·32
Roseires	+0·32	+0·31	+0·30	+0·34	+0·29	+0·28

The White Nile at Geteina and Dueim fell rapidly from the middle of September as the level of the Blue Nile at Khartoum decreased but it was not until the first week in September that the effect of the latter ceased. At Renk and the gauges to the south of it, viz., Melut, Kodok, and Taufikia, the rise continued slowly until November and in December the fall began as the volume discharged by the Sobat diminished. The gauge at Attigo and that at Meshra er Rek followed the same course, and the latter not only was unaffected by the maxima which occurred in the Jur River at Wau in August, September, and October, but did not commence to fall until the end of December where as the Jur River at Wau had been falling since November 11 and had fallen 3·5 metres since that date. It is possible that a sadd-block which occurred in the Bahr el Ghazal may have assisted to maintain the level at Meshra er Rek, but there is no marked increase of level at Meshra er Rek to show that it was interfering with the passage downstream of any considerable supply of water.

The Sobat as usual fell rapidly after the end of September at Gambela but the water from the flooded plains of the Pibor maintained the level in the Sobat until December.

Volume of flood.—The flood of 1906 may now be compared with that of previous years.

The maximum readings were :—

PLACE.	Date.	Mean Date.	Reading	Mean Reading	Difference.	No. of years in mean.
			m.	m.	m.	
Roseires	Sept. 1	Aug. 21	21·10	20·21	+0·89	7
Khartoum	„ 14	„ 31	16·51	15·98	+0·53	7
Khashm el Girba ...	Aug. 26	„ 21	15·30	14·98	+0·32	4
Berber	Sept. 8	Sept. 2	7·75	7·54	+0·21	7
Wadi Halfa	„ 14	„ 2	8·19	8·16	+0·03	17
Aswan	„ 20	„ 4	92·78	93·07	−0·29	38

The highest 5-day means were :—

PLACE.	Date.	Mean Date.	Reading	Mean Reading	Difference.	No. of years in mean.
			m.	m.	m.	
Roseires	Sept. 11-15	Aug. 16-20	20·26	18·67	+1·59	6
Khartoum	„ 16-20	Sept. 1-5	16·43	15·66	+0·77	6
Khashm el Girba ...	Aug. 21-25	Aug. 26-31	14·40	14·01	+0·39	3
Berber	Sept. 11-15	Sept. 11-15	7·69	7·18	+0.51	6
Wadi Halfa	„ 16-20	„ 1-5	8·14	7·94	+0·20	15
Aswan	„ 15-20	„ 6-10	92·73	92·78	−0·05	37

The comparison of the volume discharged is less reliable because at Khartoum alone has the volume been measured both during a rising and a falling flood, and here there is evidence of considerable variation in the channel section from year to year.

The discharge curves from which the mean number of cubic metres discharged per second in each 5–day period are taken, are based on data which are of unequal value and insufficient to furnish results of more than moderate accuracy.

Gauge.	No. of measurements.	When taken.	Place.
Khartoum	75	9· 5·02-15· 1·04	Khartoum.
	34	13· 5·02-20· 1·04	Dueim.
	10	8·11·02-18· 7·03	Kerreri.
	2	14·11·03- 1·12·03	
	7	6· 7·03-28·11·03	Shabluka.
Wadi Halfa	123	14· 5.05-20· 8·05	Sarras.
	9	10·12·05-15· 9·06	
Aswan	67	5·12·01- 6· 4·02	Wadi Halfa.
		17· 7·93-23· 9·93	Near Aswan.

From the curves based on these observations the discharge has been measured off, corresponding to each 5-day period, and compared with the mean reading for the same period, the results can only be regarded as fair approximations since changes of the river sections are not known.

Estimated Volume Discharged in Millions of Cubic Metres.

Month.	Khartoum.		Wadi Halfa.		Aswan.	
	1906	Difference from mean of 7 years.	1906	Difference from mean of 15 years.	1906	Difference from mean of 38 years.
July	6,600·1	+ 125·8	4,603·0	—2,042·5	2,795·6	—2,263·2
August	24,210·1	+3,321·6	20,031·8	—1,458·0	15,920·5	—3,794·0
September	24,818·4	+6,089·9	23,850·7	+1,944·0	22,632·5	—1,025·1
October	10,735·2	+2,421·4	15,925·7	— 320·5	15,560·2	—1,243·6
Ratio to mean flood	1·22	...	0·97	...	0·87	...

TABLE XI.—Volume discharged for each 5-day period in millions of cubic metres.

Period.		Khartoum. *			Wadi Halfa.			Aswan.		
		1906	Mean. 1900-1906	Difference.	1906	Mean. 1890-1904	Difference.	1906	Mean. 1869-1906	Difference.
July.	1-5	362·880	514·080	— 151·200	373·680	555·120	— 181·440	230·688	400·896	— 170·208
	6-10	591·840	667·872	— 76·032	419·040	637·200	— 218·160	268·704	476·496	— 207·792
	11-15	915·840	809·568	+ 106·272	475·200	775·440	— 300·240	330·480	588·384	— 257·904
	16-20	1123·200	1027·728	+ 95·472	604·800	1075·680	— 470·880	388·800	757·728	— 368·928
	21-25	1356·480	1289·952	+ 66·528	1045·440	1391·040	— 345·600	523,584	1051·488	— 527·904
	26-31	2249·856	2165·357	+ 84·499	1684·800	2210·976	— 526·176	1053·389	1783·814	— 730·425
	Total	6600·096	6474·557	+ 125·539	4602·960	6645·456	— 2042·496	2795·645	5058·806	— 2263·161
August.	1-5	3093·120	2608·848	+ 484·272	1926·720	2436·480	— 509·760	1209·600	2029·968	— 820·368
	6-10	3296·160	3114·720	+ 181·440	2808·000	3086·640	— 278·640	1872·720	2635·200	— 762·480
	11-15	3888·000	3421·008	+ 466·992	3304·800	3447·360	— 142·560	2656·800	3112·128	— 455·328
	16-20	4017·600	3585·600	+ 432·000	3672·000	3710·880	— 38·880	3032·640	3456·432	— 423·792
	21-25	4285·440	3683·664	+ 601·776	3706·560	3961·440	— 254·880	3240·000	3767·472	— 527·472
	26-31	5629·824	4474·829	+ 1154·995	4613·760	4847·040	— 233·280	3908·736	4713·293	— 804·557
	Total	24210·144	20888·669	+ 3321·475	20031·840	21489·840	— 1458·000	15920·496	19714·493	— 3793·997
September.	1-5	4739·040	3704·832	+ 1034·208	4073·760	4069·440	+ 4·320	3706·560	4053·456	— 346·896
	6-10	4743·360	3405·888	+ 1337·472	4056·480	3678·480	+ 378·000	3672·000	4056·480	— 384·480
	11-15	4773·600	3303·504	+ 1470·096	4203·360	3665·520	+ 537·840	3855·600	4046·976	— 191·376
	16-20	4017·600	3049·920	+ 967·680	4224·960	3620·160	+ 604·800	3942·000	3973·968	— 31·968
	21-25	3564·000	2786·400	+ 777·600	3697·920	3527·280	+ 170·640	3801·600	3875·040	— 73·440
	26-30	2980·800	2477·952	+ 502·848	3594·240	3345·840	+ 248·400	3654·720	3665·952	— 11·232
	Total	24818·400	18728·496	+ 6089·904	23850·720	21906·720	+ 1944·000	22632·480	23671·872	— 1039·392
October.	1-5	2548·800	2108·592	+ 440·208	3313·440	3153·600	+ 159·840	3335·040	3389·040	— 54·000
	6-10	2332·800	1728·432	+ 604·368	2905·200	2982·960	— 77·760	2838·240	3113·856	— 275·616
	11-15	1944·000	1378·512	+ 565·488	2691·360	2773·440	— 82·080	2592·000	2859·408	— 267,408
	16-20	1468·800	1110·240	+ 358·560	2505·600	2548·800	— 43·200	2462·400	2590·704	— 128·304
	21-25	1222·560	978·912	+ 243·648	2216·160	2306·880	— 90·720	2170·800	2350·080	— 179·280
	26-31	1218·240	1008·806	+ 209·434	2293·920	2480·544	— 186·624	2161·728	2500·762	— 339·034
	Total	10735·200	8313·494	+ 2421·706	15925·680	16246·224	— 320·544	15560·208	16803·850	— 1243·642
Grand total		66363·840	54405·216	+11958·624	64411·200	66288·240	— 1877·040	56908·829	65249·021	— 8340·192

* The Khartoum volumes are for the Blue Nile only, since the gauge is above the junction.

The flood of 1906 may therefore be considered as somewhat below an average flood, since the Khartoum data available were all obtained from floods which were much below the normal.

The comparison of the volume of the 1906 flood with those of previous years is given in the following table, which is based on the discharge curve of the Aswan gauge during the period July 1 to October 31 (see Plate XII).

TABLE XII.—Ratios of the Nile Floods to a Mean Flood.

Year.	Ratio to mean flood.	Year.	Ratio to mean flood.
1869...	1·18	1888	0·72
1870...	1·23	1889	1·00
1871...	1·05	1890	1·12
1872...	1·11	1891	1·01
1873...	0·84	1892	1·20
1874...	1·26	1893	0·99
1875...	1·10	1894	1·22
1876...	1·09	1895	1·15
1877...	0·70	1896	1·06
1878...	1·25	1897	0·89
1879...	1·14	1898	1·07
1880...	0·98	1899	0·63
1881...	0·93	1900	0·89
1882...	0·84	1901	0·87
1883...	1·04	1902	0·63
1884...	0·83	1903	0·89
1885...	0·99	1904	0·75
1886...	0·91	1905	0·65
1887...	1·19	1906	0·87

From this it may be seen that in volume and consequently in the amount of run-off from the Abyssinian tableland, this year's flood approximated closely to those of 1900, 1901 and 1903 :—

Place.	Maximum Gauge Reading.			
	1900	1901	1903	1906
Wadi Halfa...	8·06	8·08	8·20	8·19
Aswan	92·91	92·82	92·93	92·78

the last of these showing the closest resemblance. In both these years the early part of the rainy season was deficient, but at the end of July

and in August, there was much improvement; on the other hand in 1903 the rains continued late into September and October, causing a slow fall of the river, and producing very favourable low-stage levels in the following year. The present year is less satisfactory; the rains ceased rather abruptly at their usual time, although they were late in commencing; Addi Ugri and Addis Abbaba were in defect 3 mm. and 42 mm. respectively in September, and 0 mm. and 2 mm. in excess in October.

CHAPTER V.

It will be convenient to include here certain facts which are connected with the monsoon of East Africa and the Nile flood.

(i) Meteorological Conditions during the Monsoon Period.

The meteorological conditions in Egypt and the Sudan during the summer do not, in the light of our present knowledge, show much connection with the monsoon rains.

In April pressure was above the normal over the whole area with few exceptions; the temperature was on the whole below normal except in the southern stations; southerly winds were somewhat more prevalent than usual in the Sudan, while to the north of Khartoum they shifted to the east of north.

In May, pressure in the monsoon area remained high and the advance of southerly winds was slow; the temperature was above the normal in the Sudan, but in North Egypt below it, owing to the passage of depressions along the Mediterranean.

In June, the pressure was above normal in a narrow belt extending along the southern coast of the Mediterranean through Middle Egypt and the North Sudan to the stations in the north of the Arabian Sea. Over the European stations generally and over the Sudan, the barometer was below as well as in the North Indian Ocean stations.

In Egypt the lowest temperature values were observed early in the month, generally on the 1st, when the absolute minimum for the month was 14°0C. at Giza. In the Sudan, on the other hand, the lowest minima were recorded in the latter part of the month, the absolute value being 18° at Gallabat on the 28th.

The most noteworthy fact during June was the defect of westerliness in the winds over Egypt with corresponding excess of westerliness over the Sudan between the line Wadi Halfa—Suakin and the far south. There has also been marked increase in the southerly winds in this part, and to a less degree in Egypt. Further, as remarked above, the southerly winds of the kharif or rainy season reached a much higher latitude in the Sudan than has been the case for the past six years. This would seem to point to a movement of the southern anticyclone in a north-westerly direction together with an eastward movement of the Saharan high pressure area.

In July, over the western basin of the Mediterranean and Egypt and the Sudan up to Khartoum, the pressure was in general slightly in excess; while over East Europe and markedly over the Indian Ocean, there was a general defect from the mean.

In Egypt the highest readings were obtained on the 3rd, the absolute value being 760·2 mm. at Alexandria on that date. In the Sudan the date of maximum pressure varied much, and the maximum 760·2 mm. was recorded at Dueim on the 7th.

The lowest readings were generally obtained in Egypt on the 24th, when Suez recorded 753·9 mm., and in the Sudan about the 11th to 13th, lowest value being 752·6 mm. at Suakin.

The range was very uniform, and varied from 5·7 mm. at Suez to 3·1 at Aswan.

This effect may be attributed to the absence of depressions in the north and to the existence of uniformly settled conditions over the whole country.

The month was cooler than usual over the western and northern Mediterranean and Sudan, but slightly warmer in Egypt and more so over the North Indian Ocean.

In Egypt and the Sudan the highest temperatures were generally recorded between the 11th and 14th, after which the heat began to moderate.

The absolute values in the two countries were 47° at Aswan on the 12th and 46° at Wadi Halfa, Port Sudan and Suakin on the 12th or 13th.

These high readings may have been connected with the movement of the monsoon-centre, which lay further west than usual between the 10th and 14th.

The lowest temperatures were generally recorded in Egypt on the 1st or 2nd, and in the Sudan on various dates. The respective absolute values were 17° at Giza and Mehalla-el-Kubra and 14° at El Obeid on the 21st.

In direction the wind throughout Lower Egypt was more westerly than usual while to the south of Cairo it has been either normal or less westerly and northerly than the last five years.

In the Sudan almost everywhere the wind has blown more frequently from a quarter west of south than during the past five years which seems to point to a local intensification of the kharif during this month.

In the Sudan in August the intrusion of a valley of low pressure from the extensive depression of the monsoon again appeared, and there are signs of a corresponding valley reaching westward from the White Nile towards Kordofan and Wadai, though stations are at present too few to enable a definite statement to be made on this point.

In August the monsoon depression was as a rule shallower than during the previous month, and pressure at the centre rarely fell below 750 mm. with the principal exception from the 2nd to the 4th when the lowest pressure was under 746 mm.

Almost everywhere pressure was above normal for the month, by amounts varying from over 2 mm. in Southern Europe to a very slight excess in Egypt and the Sudan. This effect seems to be due to an intensification of the Atlantic anticyclone.

All over Egypt the maximum reading occurred on the 31st whereas in the Sudan no regularity in this respect could be observed. The absolute values were 760·5 mm. at Giza and Atbara respectively.

The lowest readings were obtained on the 3rd in general in Egypt and in the latter half of the month in the Sudan.

The absolute values were 755·1 mm. at Aswan on the 3rd and 753·4 mm. at Suakin on the 27th.

The range was very uniform and only varied from 3·2 mm. at Aswan to 5·1 at Dueim.

The month was rather warmer than usual throughout Lower Egypt, but much cooler than during the past six years in the Sudan, where the defect of temperature varied from 1°3 to 1°8.

During the month the wind direction has been more northerly than usual and the westerly component has in general been less, and even in some cases converted into an eastern cne in Egypt.

In the Sudan, on the other hand, the direction has been more westerly and as regards the frequency of the southerly component about normal, except at Mongalla, where, in place of the usual southerly wind, light northerly airs have been prevalent.

In Egypt and the Sudan the wind force or velocity has been on the whole below normal.

Forecasts.

Three forecasts were issued during the summer, at the beginning of May, July and August, dealing respectively with the prospects of the commencement of the flood, its development, and its maximum.

In the first of these, the lateness of the southerly winds in extending northwards, and the excessive rainfall in March and April in the equatorial region, together with other evidence, led to the conclusion that the flood would be somewhat late, at first weak, and probably not above the average. On July 15th, an improvement generally had taken place, the winds in the Arabian Sea were normal, and conditions seemed to point to a moderate, but not an excessive rate of rise of the flood; an average flood seemed probable, but nothing pointed to one of exceptional volume.

The same conclusion was reached by a discussion of the July rainfall, and the river levels which were reported early in August; and it will be seen that it was fully borne out by the height reached by the flood, and by the volume discharged as compared with data of previous years (see p. 44).

(ii) The Flood in the River Mareb or Khor el Gash.

The Mareb River came down in heavy flood to Kassala on the 25th and 29th July and again on August 5th and 6th, doing considerable damage. This river, known as the Mareb in its upper reaches, rises in Eritrea at an altitude of 2,200 metres above sea-level, and after a course of about 500 kilometres overflows a deltaic fan of detritus in the neighbourhood of Kassala (460 m.). It has thus an average fall of about 3·5 metres per kilometre, and in the last 100 kilometres the slope is nearly 1 in 500, if the altitudes given on the Italian maps are reliable. On this map (scale 1 : 500,000), published by the Italian General Staff, the area of the basin can be measured with some accuracy. It may be divided into a mountainous portion east of longitude 36° East of Greenwich, and a region of lower hills to the west of that meridian.

	sq. km.
Area of basin of Mareb River east of 36° E	14,500
„ „ „ west of 36°	8,810
Total	23,310

The rainfall has been measured for some years at Addi Ugri in the upper part of the basin and at Kassala.

Mean Rainfall in millimetres.

	Addi Ugri.	Kassala.
May	38	6
June	67	22
July	153	71
August	179	105

From the above data an idea of the quantity of water falling on the Mareb basin may be obtained, and if 33·3% be taken as the run-off, the average volume passing to the river valley may be approximately deduced, but in the following table only the 14,500 square kilometres east of longitude 36° E. are considered.

Month.	Volume of rain in millions of cubic metres.	Assuming 33·3% as run-off.	
		Million cubic metres per month.	or an average of cubic metres per second.
May...	551·0	183·7	70
June	971·5	323·8	125
July...	2247·5	749·2	288
August	2610·0	870·0	335

Even if the average rainfall is taken at less than the figures of Addi Ugri, or if even lower value for the run-off be assumed, there will still be a very large volume of water to pour down the steep valley-slope, usually in the form of successive flood-waves.

It is stated that the flood-water of the Gash comes down to Kassala early in July so that most of the May and June water is consumed in raising the level of the water-table from the point to which it had sunk during the dry season to one above the bed of the river. This year the rainfall at Addi Ugri and Kassala has been:—

Month.	Addi Ugri			Kassala		
	mm.	Diff. from mean.		mm.	Diff. from mean.	
		mm.	%		mm.	%
May	4	−34	−89	0	− 6	−
June	74	+ 7	+10	12	−10	− 45
July	137	−16	−10	77	+ 7	+ 10
August	176	− 3	− 2	87	−18	− 17

So that 1906 was by no means a year of excessive rainfall in this region.

By the kindness of Captain Tancredi, of Addi Ugri, I am able to give the daily rainfall measured at Addi Ugri about the time of the Kassala floods:—

July.	mm.	July.	mm.
21	0·8	26	5·5
22	14·8	27	15·2
23	0·0	28	17·1
24	1·6	29	0·9
25	4·0	30	6·2
...	...	31	1·2
August.		August.	
1	0·1	5	0·0
2	31·9	6	17·5
3	6·3	7	16·4
4	19·5	8	2·6

It is possible that the rain was heavier than this between Addi Ugri and Kassala, but the measurements clearly indicate the storms which caused the floods.

(iii) February and March rains of 1906 in the Sudan.

If we collect the rainfall statistics from the available stations, some interesting facts may be learned concerning the unusual rainstorms which occurred this year in February and March.

In February two principal falls took place, one on the 12th–13th, and the other on the 19th-21st, as the following table shows :—

Place.	Date.	mm.	Date.	mm.	Total in month.	Difference from normal
					mm.	mm.
Wadelai	12	48·3	19 20	13·5 15·2	91	+ 55
Gondokoro...	13	21·1	19	31·0	70	+ 51
Mongalla	...	...	...	...	94	+ 55
Bor	13	8·1	21	50·1	59	...
Wau	12	25·0	19	24·0	62	+ 37
Deim Zubeir	...	...	20	heavy	...	...
Ghaba Shambe... ...	13	21·5	...	...	119	+ 79
Doleib Hilla	...	...	18	66·6	72	+ 48
Tawfot	...	...	20	105·0	105	+ 70
Addis Abbaba	...	...	19	26·6		...
... ...	...	...	21	11·0	156	...
... ...	...	...	22	18·0		+108
... ...	...	...	23	31·9		...

In March a single heavy fall is recorded at most stations :—

Place.	Date.	mm.	Total of month.	Difference from mean.
			mm.	mm.
Wadelai	20 21	11·9 8·9	133	+19
Gondokoro...	19 20 21	50·8 35·6 23·9	139	+70
Bor	21	38·6	50	...
Wau	19 21	12·0 18·5	32	+17
Ghaba Shambe...	24	16·8	17	+11
Doleib Hilla	19	4·8	5	−14
Tawfot	24	11·0	11	— 2
Gambela	20 22 25	23·8 26·0 73·2	123	...
Melut (White Nile)...	20	48·0	48	...
Roseires	20	7·5	8	+ 4

At Kassala also heavy rain fell from 5 p.m. on the 15th, until 6 p.m. on the 16th, and it extended to Gedaref and Gallabat.

The mean isobars for this month are given on Plates IX and X together with those for February 13th, and 20th, while those for March 19th and 21st are represented on Plate XI. From these charts it will be seen that the rain was due to cyclonic depressions which formed in the southern Sudan and then moved is a north-easterly direction.

Similar rainstorms have no doubt occurred from time to time in the past, but no records of them exist; even unusual rises of the river are rarely mentioned except at the lowest stage, while late rises and insufficient floods were of first importance. To day, when perennial irrigation and intensive cultivation has spread from the Delta to the Nile Valley, and has already reached Assiut, floods much above the average are not beneficial, and so long as the level reached is sufficient to flood the higher lands of Aswan, Qena and Girga Mudirias, any flood is satisfactory. It is quite otherwise with the low stage supply; in April, May, June and July all available water is required for agriculture, and of late years large works have been erected to store up the surplus water of December and January in order to distribute it later, in the season of insufficient river supply. Any assistance such as that received this year from the Abyssinian and Sudan rains of February and March, is of inestimable value, and their probable frequency is a matter of special interest. We have seen that the flood-wave of February took 30 days to travel from Roseires to Wadi Halfa, and had the Aswan Reservoir not existed, would have taken about 15 to 18 days longer to reach Cairo. It follows, therefore, that rainstorms on the Abyssinian tableland on February 15 would, if heavy enough, affect the level at Cairo about April 1 and those on March 15 about May 1, passing Aswan about 10 days earlier.

The data available for this investigation are meagre; they consist of, a few travellers' accounts, the daily gauge readings at the Delta Barrage for the years 1845-1861, and the daily gauge readings at Aswan from to the present time.

In 1847, about March 15, the river at the Barrage stopped falling, and during ten days rose slightly, after which the usual fall recommenced. On May 5, a similar rise took place which affected the level for about three weeks. These rises were undoubtedly due to heavy rainfalls in Abyssinia, and the one which caused the marked rise must have occurred quite at the beginning of February. Of the 16 years recorded, 1847 is the only one which shows so early a rise but in 1852 there was one in

May, but not earlier. The curves from which the above data are taken * are plotted from 5-day means, and small rises may thereby have been flattened out.

From the records of the river level at Aswan, the following cases of early rises may be taken, from which it may be seen that only twice would such rises have corresponded with February rain in Abyssinia, and in each case they must have been near the end of the month.

Year.	Period of rise at Aswan.	Total rise cm.	Approximate date of rain in Abyssinia.	Remarks.
1872	April 18-30	7	March 10	
1874	„ 28-May 7	11	„ 24	
1877	„ 13-30	25	„ 6	
1877	May 1-14	7	„ 23	
1879	April 21-28	11	„ 14	
1879	„ 29-May 6	6	„ 22	
1881	„ 11-18	5	„ 4	
1886	„ 18-May 4	12	„ 11	
1887	„ 21-29	7	„ 24	
1888	„ 4-10	9	Febr. 25	
1889	May 1- 9	9	March 23	
1891	April 18-23	7	„ 11	
1893	„ 5-12	9	Febr. 23	
1894	„ 17-21	12	March 10	
1896	„ 29-May 5	5	„ 22	
1900	„ 24-May 14	9	„ 17	

The later March rains are probably only early storms of the usual "Azmera" or spring rains of Abyssinia but they are none the less of value in improving the low-stage levels of the Nile.

On Plate XIII the curves of the Nile gauge readings at Aswan and Wadi Halfa as the level falls from the maximum in the autumn to the minimum in early summer are shown graphically. From these it will be seen that in several years the rate of fall has been alruptly checked which can only have been due to an increased discharge passing down the river; the result of rainstorms in the basin of the Blue Nile.

* Zeitschrift für allgemeine Erdkunde N. F. Bd. XIV, Taf II.

(iv) The low-stage supply of the Nile.

Measurements of the volume discharged by the Nile at different seasons seemed to show that during the rise and full of the flood a very large amount of water was lost by seepage into the Nubian sandstone, but probably at lowest stages an appreciable addition was made to the river supply since the water-level was probably below the watertable at this time. The following discussions of the results is by Mr. J. I. Craig.

A series of discharges were taken at Kareima * on April 10-13 as part of an organised investigation of the flow of water to or from the Nile by seepage. Discharges measured at Sarras and at Aswan Reservoir, but by different methods, seemed to show the possibility of considerable quantities of water leaving the river in January and February between these two places. Accordingly it was decided to take systematic observations at Kareima, which, supplemented by the regular measurements at Sarras and the data afforded by the regulation of Aswan Reservoir, might facilitate a discussion of the question. Owing, however, to the absence of the Inspector General of Irrigation from Khartoum, a regular set of discharges was not available for that station, and interpolated values had to be used.

Method.—The method employed of late years in all operations for measuring the discharge of the Nile was followed. A site was selected almost opposite Kareima station, where the river was narrowest at this season, and a rope was stretched across the river with the help of a steamer, kindly placed at the disposal of the party by Col. Jackson. By anchoring a small boat in mid-stream, to take the weight of the rope, it was found possible to get this almost straight across the river, and no correction was required for sag.

A Price's current meter was used to find the velocities, and a sounding-line, marked in metres, was used to measure the depth. Distances from the bank were measured along the rope with a ten-metre cord, which was checked before and after a measurement. The sounding-line was also checked.

The direct distance across the river was measured with a tacheometer, and found to be 192·7 metres at the first site (for the first two discharges), and 194·0 metres at the second site, which only differed slightly from the former.

---

* Downstream of the Fourth Cataract.

Two sets of velocity-measurements were taken to determine the position of the filament of mean velocity, from which it was concluded that no correction need be applied to the velocity at mid-depth, at which all the stream velocities were measured, to reduce the observed velocities to the average velocity in the vertical.

The current-meter was rated immediately on the return of the party, and the following rating equation found:—

$$y = 0{\cdot}8995\ x + 0{\cdot}1442$$

were y is the velocity of the water in metres per second and x the number of revolutions of the meter per second. Another rating was made in June which gave the equation:—

$$y = 0{\cdot}8991\ x + 0{\cdot}0637$$

It thus appears that the behaviour of the meter was consistent.

Identification of corresponding discharges.—It is, of course, essential to be sure that the same water that passed Khartoum was being measured at Kareima and Sarras, a point which was somewhat complicated, but also somewhat simplified, by the fact that a floodpulse, due to usually early rain in Abyssinia, was passing down the river at the time. Had the river been falling uniformly at each place, it would have been extremely difficult to identify at the lower stations the water already measured at Khartoum. The passing of the flood-pulse, however, removed some of the uncertainty, and, had the measurements extended over the whole time of the pulse, the uncertainty would have entirely disappeared.

It is possible to fix the interval between the passage of a given volume of water at Khartoum and its subsequent appearance at Kareima and Sarras by the following considerations. The gauge-readings at Khartoum, Sarras and Halfa show that the flood-pulse passed the different stations at the times indicated in the table.

DATE OR ARRIVAL OF.

	The 1st rise.	The crest.	The end.	Mean.
Khartoum	April 4	April 7	April 13	...
Sarras	„ 19	„ 24	„ 29	...
Wadi Halfa	„ 23	„ 25	„ 30	...
Interval in days. Khartoum-Sarras ...	„ 15	„ 17	„ 16	16
Interval in days. Khartoum-Wadi Halfa.	„ 19	„ 19	„ 17	18

We have the following data * as to distances along the river in reach :—

Khartoum-Wadi Halfa	1,530	kilometres.
Khartoum-Merowe	815	„
Now Sarras to Wadi Halfa is	50	„
and Kareima to Merowe is	9	„
Therefore Khartoum to Kareima... ...	806	„
Khartoum to Sarras	1,480	„
Khartoum to Wadi Halfa	1,530	„

If the data of the Sarras gauge be employed, the mean rate of travel of the pulse was 1480 kilometres in 16 days, or 92·5 kilometres per day, while with the Wadi Halfa data the speed becomes 85·0 kilometres per day. It is probable that a mean, or 88·7, will be a better value to adopt. With this value, the time from Khartoum to Kareima should be 9 days, and the times of arrival of the different phases at Kareima should be:—

First rise of the pulse...	April 12
Crest	„ 16
End...	„ 22

These times depend, of course, on the assumption that the pulse moved uniformly along the river, but it is almost certain that it would be retarded slightly as it advanced, and would accordingly move more slowly in the latter part of its journey. On this assumption, the first rise of the pulse might be expected at Kareima about April 11 or 12, and it therefore appears that the discharges, which extended from April 10-13, were taken on the rise due to the passage of the pulse. That the river was rising is shown by the readings of a temporary gauge erected at Kareima on April 11, which were :—

April 11	0·40 cm. at noon	
„ 12	0·48 cm. a.m.	0·49 cm. p.m.
„ 13	0·49 cm. a.m.	

These figures agree with the contention that the passage of the pulse took place before the times derived from the assumption of a uniform speed.

The average time from the first rise to the passage of the crest, was:—

At Khartoum...	3	days.
„ Sarras	5	„
„ Wadi Halfa	2	„
Mean	3·3	„

* "Physiography of the River Nile." Cairo, 1906 p. 5. Two kilometres have been allowed for the distance from the gauge at Khartoum to the confluence.

If, therefore, we take the first rise at Kareima as occurring on the 11t the crest passed at a late hour on the 14th, so that the highest dischar obtained did not correspond with the passage of the actual crest.

It is noteworthy, as will appear later, that the water passed Karein in a series of waves, and not as one continuously flowing and ebbi pulse. The coincidence between the shapes of the gange curves showi the two discharges is too striking to be the result of chance, and mu correspond to a real phenomenon. There were thus two maxima the discharge and there is very little doubt that it was the first of the or a secondary maximum, which was measured at Kareima on t afternoon of the 12th. This fact would again point to the crest ha ing passed Kareima on the 14th.

Discharges.—Khartoum.—Mr. Dupuis kindly supplied the figur from which the following data have been extracted :—

OBSERVED DISCHARGES NEAR KHARTOUM.

DATE.	Blue Nile.	White Nile.	Nile.	REMARKS.
March 24-26	219 m³ per sec.	511 m³ per sec.	700 m³ per sec.	"All see
April 11-13	254 „	581 „	817 „	too low.
May 1-2	104 „	635 „	724 „	

DEDUCED PROBABLE DISCHARGES OF THE NILE AT KHARTOUM.

March	30	780	cubic metres per second
„	31	796	„
April	1	818	„
„	2	796	„
„	3	777	„
„	4	777	„
„	5	826	„
„	6	896	„
„	7	935	„
„	8	910	„
„	9	890	„
„	10	865	„

...d from a rough curve.

It will be observed that the phenomenon of the double crest also at Khartoum, but with an interval of six days between the The discharges were interpolated from observed figures, a considerable interval, and accordingly too much stress sho laid upon them. Mr. Dupuis remarks : "The period chos

observations was unlucky—the river was behaving very oddly all through March and April—we had two very respectable little flushes down the Blue Nile and all gauges were very irregular."

As has been remarked, there are not wanting compensating advantages.

Kareima.—The corrected results for this station were * :—

Date.	Discharges cub. m. per sec.	Sectional area sq. met.	Mean velocity met. per sec.
April 10 evening	865	1003	0·798
„ 11 morning	798	1005	0·794
„ 12 morning	865	1059	0·818
„ 12 evening	885	1099	0·805
„ 13 morning	887	1090	0·814

Sarras.—The discharges here gave the following results:—

April 19	Discharge	787	cub. met. per second.
„ 20	„	722	„
„ 21	„	819	„
„ 22	„	803	„
„ 23	„	883	„
„ 24	„	867	„
„ 25	„	803	„

Comparative Results.—Khartoum-Sarras.—The first rise passed the former station on April 4, and the latter on the 29th, while the corresponding times for the principal crests were April 7 and 24 respectively. Daily discharges were not measured at Sarras after April 25, but from a comparison of the results to that date, the following figures result;—

Khartoum.		Sarras.		
Date.	Discharge in cub. met. per sec.	Date.	Discharge in cub. met. per sec.	Difference in cub. met. per sec.
April 3	777	19	787	−10
„ 4	777	20	722	+55
„ 5	826	21	819	+ 7
„ 6	896	22	803	+93
„ 7	935	23	883	+52
„ 8	910	24	867	+43
„ 9	890	25	803	+87
			Mean	+47

* The marked similarity between the curves of discharge at Kareima and Sarras strengthens confidence in the accuracy of both and in the deductions made from them.

It would thus appear that, on the average, 47 cubic metres per second more were passing at Khartoum than at Sarras. The effects of evaporation, seepage and filling of the trough have, however, to be considered.

If we consider the trough of a river and the space included between two sections, the free water surface and the bed, it is evident that the excess of the quantity of water flowing into the region at the upstream section over that flowing out at the down-stream section must be exactly equal to the sum of that evaporated, that lost in seepage, and that employed in raising the general level of the free surface.

In symbols:—

Let Q be the number of cubic metres per second passing down across the upper section,
q be the corresponding quantity of the same water passing out across the lower section,
E be the amount of water evaporated from the whole section in one second, measured in cubic metres,
S that lost from seepage in a second,
T the amount of the layer added per second to the water already in the trough by rise of the surface.

then the statement made above is embodied in the following equation:—

$$Q = q + S + E + T.$$

If now A is the area of the free water surface in square metres,
e, the daily evaporation of the water surface in metres,
h, the mean rise per day measured in metres,
then $E = eA/86400$
„ $T = hA/86400$ and the equation becomes:—

$$Q = q + S + A(e + h)/86400$$

Now the gauge readings show that the flood-pulse left no permanent rise in the river between Khartoum and Sarras, since after its passage they were almost exactly the same as before. No water was therefore abstracted from that passing Khartoum to raise the level of the free surface, and accordingly h may be put zero.

The amount of the dally evaporation is more doubtful. Observations of this element have only recently been commenced in the Sudan, and data are available for the stations Wadi Halfa, Merowe, Berber and

Khartoum, at each of which a Piche evaporimeter exposed in a louvred screen is in use. The mean daily evaporation found in April was:—

Wadi Halfa	16·8 mm.
Merowe	23·2 „
Berber...	24·0 „
Khartoum	13·1 „
Average	19·3 mm.

Recent work at Helwan Observatory indicates that the evaporation from a free water surface is 0·95 of that from a Piche evaporimeter, whereas experience in the United States gives the ratio as more nearly 0·75. With the former the evaporation from the river would be 18·3 mm. daily, and with the latter 14·5 mm. Pending more definite information on this point, calculations will be based on evaporations of 20 and 15 mm. between which the true value will probably lie.

The area of the free surface is also somewhat doubtful. Parts of this reach (roughly, half) have been surveyed on the scale 1 : 10,000, but for the remaining parts the maps on the scale 1 : 250,000, published by the Topographical Division of the General Staff, London must be used, and it is probable that the margin of the river shown on these is the flood limit. It will therefore require modification to give the area of the river in April, a remark which also applies to the larger scale maps which were all surveyed when the river was considerably higher. Probably 20% is a fair deduction to make from the areas measured from the maps, which are shown in the table:—

	Area.		Distance.	Mean breadth.
	From the maps mill. sq. met.	Less 20% mill. sq. met.	km.	met.
Khartoum-Kareima...	722	578	806	720
Kareima-Sarras ...	604	483	674	720
Total ...	1,326	1,061	1,480	720

Since we may put h equal to zero in the above equation, and e is taken to be 20 mm., the equation becomes:—

$$Q = q + S + 1061 \times 10^6 \times 0{\cdot}020/86400$$
$$= q + S + 246$$

But $Q - q$ has been shown to be 47, and so

$$47 = S + 246$$

or $S = 199$

In other words, water to the amount of 199 cubic metres per second was found to be *flowing into* the river from the banks.

If the evaporation be assumed to be 15 mm., this figure is reduced to 138 cubic metres, and it may be stated with considerable certainty that a quantity of from 140 to 200 cubic metres per second was entering the river between Khartoum and Sarras. This might well be, as the river was then almost at its lowest stage and the water-table would accordingly be above the river surface.* A certain quantity would, without doubt, come from the Atbara, where underground flow has been recently demonstrated † but the greatest amount would be that oozing from the banks and welling from springs, while some may also flow in from the beds of the wadis. ‡

Kareima-Sarras.—After the discussion devoted to the Kareima-Sarras data, it will be unnecessary to elaborate the figures derived from the Kareima-Sarras reach. It is sufficient to quote them, and to point out that they entirely support the other measurements.

In tabular form, the corresponding discharges are:—

Kareima.			Sarras.		
Date.	Discharge.		Date.	Discharge.	Difference.
April	Cub. m. per sec.		April	Cub. m. per sec.	Cub. m. per sec.
10 p.m.	865		19	787	88
11 a.m.	798		20	722	76
12 a.m.	865	Mean 875	21	819	56
12 p.m.	885				
13 p.m.	887		22	803	84
				Mean	74

With an evaporation of 20 mm. daily, the flow of water into the river becomes 39 cubic metres per second, while with 15 mm. daily, the amount is reduced to about 10 cubic metres per second.

* That the water-table is above the free surface of the river is confirmed by a statement of Col. Jackson, the Mudir of Dongola province, that well water is found at a less depth back from the river than it is on the banks.

† "Physiography of the River Nile," Cairo, 1906. p. 235.

‡ As is found to be the case in several wadis between the Nile and the Red Sea.

It thus appears that between Khartoum and Sarras water to the amount of 200 to 140 cubic metres a second was flowing into the river, while between Kareima and Sarras the quantity was from 40 to 10, according to the amount assumed for daily evaporation. For reasons already mentioned, the second result is probably slightly more reliable than the first, but it seems probable that in any case the return flow into the river from seepage is somewhat greater in the upper reach than in the lower, and that this diminution is continued in the reach between Wadi Halfa and Aswan, where the direction of flow of the sub-surface water may even be reversed.

What probably happens, therefore, is that on the full flood, while the level of the river is above the water-table, seepage from the river is proceeding everywhere, but to an extent which we can only conjecture, though it is certain that the quantity so lost must be measured in hundreds of cubic metres per second. After a time, as the water-surface falls, a point is reached when there is equilibrium between the river and sub-surface water, but the date of this phenomenon varies for different reaches, and depends mainly on the porosity of the banks. In very porous material, the water-table may be permanently below the level of the river surface, in which case there will be seepage from the river permanently, reaching a maximum in flood and a minimum at the lowest stage. In less porous material, the level of the water-table will rise and will oscillate about a mean position which will approximate to, but not in general exceed, the mean gauge reading of the river, except where an independent supply of underground water is available. In the latter case, which is probably that of the Nile between Khartoum and Kareima, seepage from the river will operate while the river is above the mean gauge reading, but the flow will be reversed almost as soon as the surface falls below the mean.

On Plate XIII the fall of the Nile at Aswan and Wadi Halfa has been plotted for each year that data exist, in order to show in what years the normal fall of the water level has been checked when it was nearing its lowest limits. The curves on Plate XIII are plotted from the maximum and minimum readings of the year, and from those of the 1st and 15th of each month from August to July.

In countries where the rainfall is distributed throughout the year, rivers may rise in flood at different seasons, having a principal flood season, and other minor floods due to unusually heavy rains. The Nile by reason of its geographical position, having its principal catchment area, Abyssinia, situated within the tropics, has a simple regimen.

Annual rains, commencing in May, reaching their maximum in August, and rapidly decreasing in September cause a flood which rises rapidly at in July and August, reaches its maximum early in September, falls first rapidly in October, and then more slowly as the low-stage of the river is approached. These tropical rains begin and end with great regularity, and when they are ended, a practically rainless season, lasting for 6 or 7 months, sets in, so it is on the intensity and duration of these tropical rains that the variations of the low-stage level depend.

The first rise of the Nile takes place at Khartoum usually in the last days of May, and while at first the increase of level is slow, it becomes rapid in July and August reaching the maximum about the first week in September on the average. The rains in Abyssinia now are decreasing greatly in intensity, and have practically ceased in the basin of the Blue Nile by the middle of October, so that the fall of the river is now rapid. Craig has discussed the effect of this rapid rise of the Blue Nile flood on the water of the White Nile, and as shown that:—

(1) As soon as the level of the water at Khartoum has risen 2·5 metres, the water surface here and at Dueim begins to rise at very nearly the same rate, since the White Nile valley upstream of Omdurman then contains a practically horinzontal sheet of water.

(2) This reservoir of water continues to rise as long as the Blue Nile rises, and the water coming down the White Nile, which is at this season mostly from the Sobat, is more than sufficient to keep up the level.

(3) The volume of water so stored amounts to about 1,500 millions of cubic metres in an average year.

(4) As the Blue Nile falls, this reserve of water is discharged, increasing the supply and causing levels in the Nile to fall more slowly than in the Blue Nile.

The factors therefore which affect the low-stage levels of the river are:—

(*a*) The intensity of the rainfall in Abyssinia.
(*b*) Its continuance into September and October.
(*c*) The volume stored in the valley of the White Nile.
(*d*) Rainstorms in the months November to April which temporarily raise the water-level.

The first three of these factors are directly connected with the short and heavy rainfall which ceases in October.

The last factor above-mentioned is a disturbing one, but the rare occurrence of heavy rainstorms in the dry season renders it less effective

than in many other rivers. Until the last few years, the want of gauges on the Blue Nile prevented us from ascertaining if such rises occurred, and when records were kept at Khartoum from 1869 to 1883, the readings during the flood period alone were registered.

As from December to April no rain is ordinarily falling in the Blue Nile Basin, it is fair to conclude that such additional supply of water is derived from such occasional rainstorms as we have been discussing. Rainfall in North Uganda will not affect the river level at Wadi Halfa, as the marshy flood-plain of the Bahr el Jebel valley will take up any increased supply, while flood waves in the upper tributaries of the Sobat die out in the long course of that river and the shallow valley of the White Nile.

The average rate of fall of the river at Aswan, deduced from 30 years' observations, is :—

Month.	Fall in cm.	Month.	Fall in cm.
September	58	January	69
October	215	February	64
November	154	March...	63
December	122	April	44

so that the fall in October is that which has most effect in determining the low-stage level. As the river is higher in September than in October, larger volumes of water are passing per second in that month than in October, when the velocity is considerably less, and from the discharge table the proportionate discharge in September, October and November may be taken very approximately as :— 1·4 : 1 : 0·55.

It will be seen from Plate XIII that in several years an abrupt change in the slope of the curve shows that an increased supply of water has passed down the river: 1872, 1875, 1892, 1898 and 1905 may be quoted as the most marked instances of this. If the case of this year may be considered as typical, it is from the Southern Sudan that these rain-bearing depressions come, so that it is most desirable to promote the study of the meteorology of this region. With only a few years' observations at a few stations at present available, but little can yet be done in elucidating their cause.

In Egypt the effect upon the supply was very noticeable, and the following table* shows to how appreciable an extent the supply of the large canals was benefitted:—

Wadi Halfa.						Aggregate discharge of Ibrahimia and Delta Canals in M^3 p. s.			
Date.	Reading.		Discharge m^3 p. s.†		Difference %	Date.	1905	1906	Difference %
	1905	1906	1905	1906					
	m.	m.							
March 10	1·54	1·52	830	790	— 5	April 1	735	780	+ 6
„ 25	1·36	1·60	730	830	+ 14	„ 15	650	740	+ 14
April 10	1·23	1·39	700	745	+ 6	May 1	590	765	+ 30
„ 25	1·14	1·60	670	830	+ 25	„ 15	620	790	+ 28
May 10	1·04	1·30	630	710	+ 12	June 1	540	740	+ 37
„ 27	0·94	1·20	600	690	+ 15	„ 15	590	740	+ 25
June 12	0·93	1·10	590	675	+ 14	July 1	640	780	+ 22
July 1	1·30	1·54	710	830	+ 17	„ 15	780	860	+ 11

Note.—The Delta Barrages were both tightly closed by the end of March in both years.

The Aswan reservoir commenced to supply the region to the north of it on May 1st in 1905, and on May 10th in 1906. The rate of supply was almost exactly the same in both years.

* From the Inspector General of Irrigation for Lower Egypt.

† From a discharge curve derived from the Sarras discharges given in Appendix 1.

APPENDIX

Volumes of the Nile Discharged at Sarras, 1906.

No.	Date.	Gauge.	Mean Velocity m. p. s.	Position of Mean velocity below surface.	Cross Section m².	Width in metres.	Mean depth metres.	Area on unchanged section.	% difference.	Discharge c. m. p. s.	Discharge from curve.	% difference.	No. days to reach Halfa.	Relative gauge readings Halfa.
1	2 January.	3·92	0·63	0·65	2476	169·5	16·3	...	...	1570	1630	3·7	0·9	2·60
2	6 „	3·81	0·61	0·65	2566	169·5	15·3	...	...	1567	1560	0·4	1·0	2·56
3	9 „	3·70	0·56	0·65	2545	168	15·2	...	...	1431	1510	5·2	1·0	2·50
4	11 „	3·66	0·59	0·65	2543	168	15·2	...	...	1525	1490	2·3	1·0	2·48
5	14 „	3·61	0·61	0·65	2524	168	15·0	...	...	1549	1460	6·1	0·9	2·45
6	17 „	3·52	0·57	0·65	2521	168	15·0	...	...	1441	1420	1·5	1·0	2·42
7	20 „	3·48	0·56	0·65	2507	168	14·9	...	...	1403	1400	0·2	1·0	2·38
8	22 „	3·35	0·53	0·75	2495	168	14·8	...	...	1323	1340	1·4	1·1	2·32
9	25 „	3·32	0·57	0·65	2491	168	14·8	...	...	1423	1320	7·8	1·0	2·31
10	27 „	3·32	0·55	0·65	2495	167	14·9	...	...	1362	1320	3·2	1·1	2·30
11	30 „	3·27	0·54	0·75	2466	167	14·8	...	...	1323	1300	1·8	1·1	2·26
12	1 February.	3·21	0·54	0·65	2461	167	14·7	...	...	1316	1270	3·6	1·1	2·25
13	5 „	3·05	0·50	0·75	2414	166	14·5	...	...	1210	1200	0·8	1·1	2·17
14	7 „	2·93	0·53	0·65	2403	166	14·5	...	...	1210	1160	4·3	1·1	2·11
15	8 „	2·90	0·48	0·65	2399	165	14·5	...	...	1149	1150	0.1	1·2	2·07
16	11 „	2·86	0·47	0·65	2416	165	14·6	...	...	1137	1140	0·3	1·2	2·02
17	13 „	2·76	0·46	0·65	2381	165	14·4	...	...	1094	1090	0·4	1·2	2·00
18	15 „	2·70	0·50	0·65	2374	165	14·4	...	...	1184	1070	10·7	1·2	2·02
19	16 „	2·69	0·46	0·65	2374	165	14·4	...	...	1080	1070	0·9	1·3	1·99
20	20 „	2·52	0·43	0·65	2320	164	14·3	...	...	1003	1020	1·7	1·3	1·77
21	22 „	2·41	0·42	0·65	2308	164	14·1	...	...	970	980	1·0	1·4	1·77
22	23 „	2·36	0·44	0·65	2294	164	14·0	...	...	1001	975	2·7	1·3	1·78
23	25 „	2·34	0·42	0·65	2287	164	14·0	...	...	954	970	1·7	1·4	1·76
24	1 March.	2·07	0·36	0·75	2253	164	13·7	...	...	819	880	6·9	1·6	1·64
25	2 „	2·04	0·37	0·65	2242	162	13·8	...	...	824	870	5·3	1·6	1·63
26	4 „	2·00	0·37	0·75	2244	162	13·8	...	...	828	860	3·7	1·6	1·63
27	8 „	1·74	0·34	0·65	2200	162	13·5	...	...	745	800	6·9	1·7	1·54
28	9 „	1·68	0·32	0·65	2232	162	13·8	...	...	723	790	8·5	1·8	1·48
29	13 „	1·71	0·39	0·55	2203	162	13·6	...	...	860	790	8·9	1·5	1·46
30	15 „	1·60	0·36	0·65	2165	162	13·4	...	...	788	770	2·3	1·6	1·44
31	17 „	1·69	0·42	0·66	2179	162	13·5	...	...	914	790	15·7	1·4	1·48
32	20 „	1·80	0·40	0·66	2204	162	13·6	...	...	870	815	6·8	1·5	1·54
33	22 „	1·76	0·38	0·66	2207	162	13·6	...	...	838	810	3·5	1·5	1·49
34	23 „	1·83	0·39	0·66	2226	162	13·7	...	...	857	830	3·2	1·5	1·54
35	26 „	1·90	0·39	0·61	2221	162	13·7	...	...	894	840	6·4	1·4	1·63
36	28 „	1·88	0·39	0·61	2191	162	13·9	...	...	854	830	2·9	1·5	1·58
37	29 „	1·86	0 37	0·61	2209	162	13·6	...	...	821	830	1·1	1·5	1·56
38	31 „	1·79	0·39	0·61	2218	162	13·7	...	...	871	815	6·9	1·5	1·55
39	2 April.	1·71	0·38	0·61	2189	162	13·5	...	...	826	790	4·6	1·5	1·51
40	5 „	1·56	0·42	0·61	2145	162	13·2	...	...	910	770	18·2	1·4	1·44
41	7 „	1·51	0·34	0·61	2140	162	13·2	...	...	727	750	3·1	1·7	1·40
42	10 „	1·51	0·35	0·65	2154	162	13·3	...	...	746	750	0·5	1·7	1·40
43	11 „	1·52	0·36	0·65	2139	162	13·2	...	...	765	750	2·0	1·6	1·41
44	13 „	1·50	0·35	0·65	2124	162	13·1	...	...	739	750	1·5	1·7	1·40
45	14 „	1·53	0·35	0·65	2142	162	13·2	...	...	740	750	1·3	1·7	1·40
46	15 „	1·55	0·36	0·65	2135	162	13·2	...	...	777	750	3·6	1·6	1·40
47	16 „	1·55	0·38	0·65	2145	162	13·2	...	...	818	750	9·1	1·5	1·41
48	17 „	1·57	0·33	0·65	2155	162	13·3	...	...	712	760	6·3	1·7	1·42
49	18 „	1·55	0·35	0·65	2141	162	13·2	...	...	759	750	1·2	1·6	1·41
50	19 „	1·55	0·37	0·65	2134	162	13·2	...	...	787	750	4·9	1·6	1·41
51	20 „	1·58	0·34	0·65	2142	162	13·2	...	...	719	760	5·4	1·7	1·41
52	21 „	1·65	0·38	0·65	2162	162	13·2	...	...	819	780	5·0	1·5	1·39
53	22 „	1·75	0·36	0·65	2182	162	13·4	...	...	792	800	1·0	1·6	1·48
54	23 „	1·82	0·41	0·65	2182	162	13·4	...	...	883	830	6·4	1·4	1·57
55	24 „	1·83	0·40	0·65	2189	162	13·5	...	...	867	830	4·5	1·5	1·60
56	25 „	1·82	0·37	0·65	2185	162	13·5	...	...	803	830	3·3	1·6	1·57

APPENDIX (*continued.*)

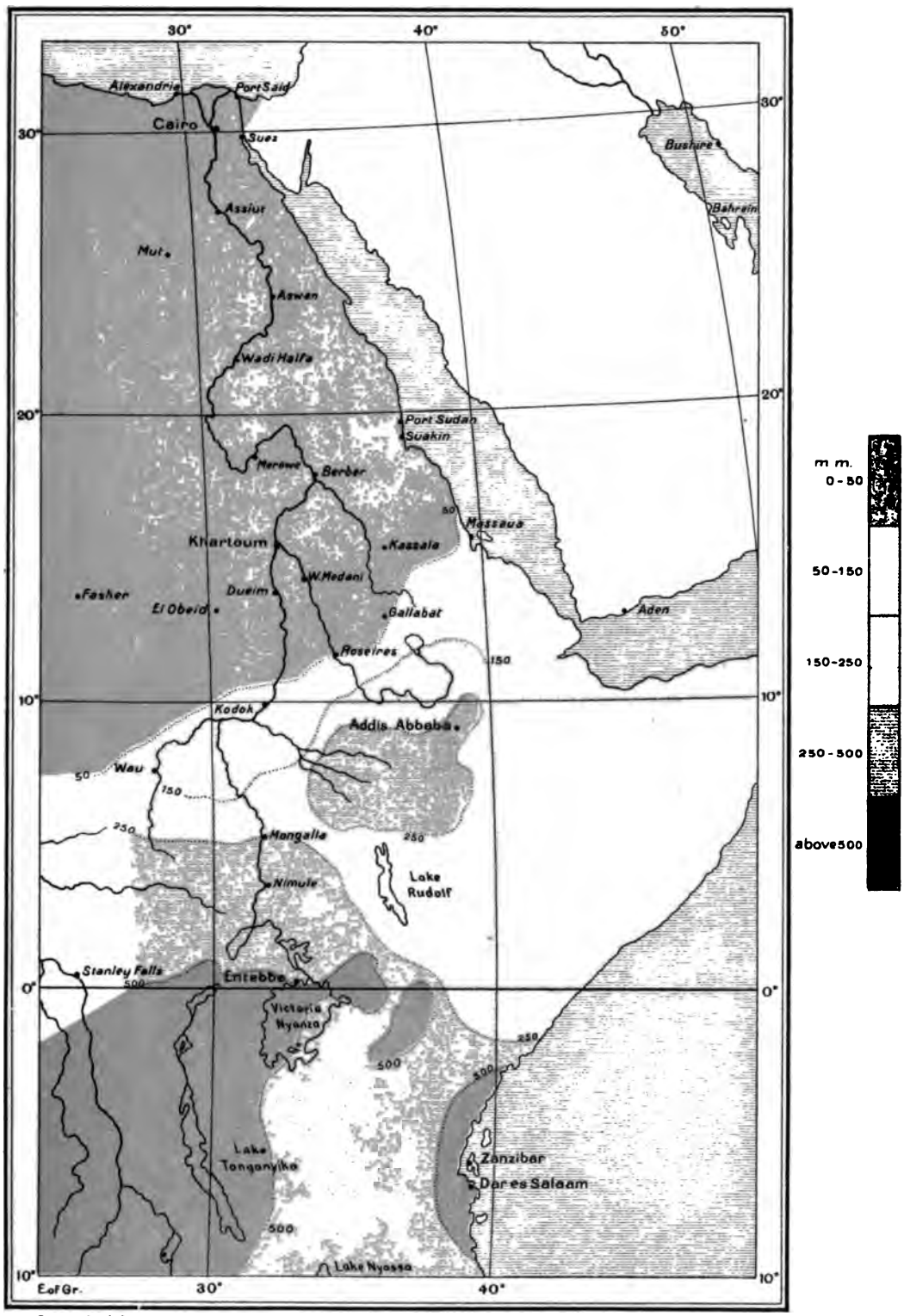
No.	Date.	Gauge.	Mean velocity m. p. s.	Position of mean velocity below Surface.	Cross section m².	Width in metres.	Mean depth metres.	Area on unchanged section.	% difference.	Discharge c. m. p. s.	Discharge from curve.	% difference.	No. days to reach Halfa.	Relation gauge
57	1 May.	1·51	0·37	0·61	2143	162	13·2	...	...	787	750	4·9	1·6	
58	2 „	1·49	0·36	0·61	2134	163	13·2	...	...	763	740	3·1	1·6	
59	3 „	1·44	0·36	0·61	2125	163	13·1	...	...	765	730	4·8	1·6	
60	10 „	1·28	0·35	0·61	2091	163	12·9	...	...	728	700	4·0	1·7	
61	11 „	1·25	0·35	0·61	2102	163	12·9	...	...	761	700	8·7	1·6	
62	12 „	1·19	0·32	0·61	2083	163	12·9	...	...	663	690	3·9	1·8	
63	15 „	1·12	0·33	0·61	2088	163	12·9	...	...	696	690	0·9	1·7	
64	17 „	1·14	0·33	0·61	2102	163	12·9	...	...	699	670	4·3	1·7	
65	19 „	1·09	0·30	0·61	2105	161·5	13·0	...	...	630	660	4·5	1·9	
66	22 „	1·11	0·33	0·61	2088	161·5	13·0	...	...	692	670	3·3	1·7	
67	24 „	1·14	0·34	0·61	2100	161·5	13·0	...	...	722	670	7·8	1·7	
68	25 „	1·12	0·31	0·61	2098	161·5	13·0	...	...	655	670	2·2	1·8	
69	27 „	1·10	0·33	0·61	2091	161·5	12·9	...	...	680	670	1·5	1·8	
70	29 „	1·06	0·30	0·61	2086	161	12·9	...	...	623	660	5·6	2·0	
71*	7 June.	0·97	0·27	0·60	2249	215	10·5	2223	+ 1·1	600	640	6·3	2·1	
72	15 „	0·98	0·27	0·60	2251	215	10·5	2223	+ 1·3	600	640	6·3	2·1	
73	16 „	1·06	0·31	0·60	2256	215	10·4	2244	+ 0·5	707	700	1·0	1·8	
74	18 „	1·27	0·31	0·60	2326	218	10·6	2288	+ 1·7	701	730	4·0	1·8	
75	22 „	1·58	0·34	0·60	2363	219	10·8	2353	+ 0·4	813	810	0·4	1·7	
76	23 „	1·62	0·34	0·60	2351	219	10·7	2353	...	803	815	1·5	1·7	
77	26 „	1·60	0·36	0·60	2347	219	10·7	2353	...	840	810	3·7	1·6	
78	27 „	1·62	0·35	0·60	2346	219	10·7	2353	...	819	815	0·5	1·6	
79	1 July.	1·71	0·36	0·62	2381	220	10·8	2376	...	862	830	3·9	1·6	
80	2 „	1·78	0·37	0·62	2435	220	11·0	2398	+ 1·5	898	860	4·4	1·5	
81	3 „	1·86	0·37	0·62	2473	220	11·2	2419	+ 2·2	917	880	4·2	1·5	
82	4 „	2·00	0·39	0·62	2516	224	11·2	2441	+ 3·1	986	920	7·2	1·5	
83	7 „	2·07	0·40	0·62	2523	224	11·2	2463	+ 2·4	1010	940	7·5	1·4	
84	8 „	2·33	0·41	0·62	2549	225	11·3	2507	+ 1·7	1031	1030	0·1	1·4	
85	10 „	2·45	0·42	0·62	2593	225	11·5	2540	+ 2·1	1075	1070	0·5	1·4	
86	11 „	2·53	0·42	0·62	2614	225	11·6	2558	+ 2·5	1099	1100	0·1	1·4	
87	15 „	2·85	0·44	0·62	2645	226	11·7	2630	+ 0·6	1151	1225	6·0	1·3	
88	22 „	5·12	0·76	0·62	3196	238	13·4	3153	+ 1·4	2444	2420	1·0	0·8	
89	24 „	5·51	0·82	0·63	3247	240	13·5	3248	...	2658	2670	0·5	0·7	
90	27 „	6·12	0·88	0·63	3432	241	14·3	3392	+ 1·2	3018	3100	2·6	0·7	
91	1 August.	7·21	1·07	0·62	3865	244	15·8	3659	+ 5·6	4154	3860	7·6	0·5	
92	3 „	7·63	1·16	0·62	3925	246	15·9	3758	+ 4·4	4559	4510	1·1	0·5	
93	5 „	8·28	1·35	0·62	4006	248	16·4	3932	+ 1·9	5396	5200	3·8	0·4	
94	8 „	9·90	1·67	0·62	4266	256	16·6	4337	— 1·6	7112	7550	5·8	0·3	
95	11 „	10·60	1·70	0·62	4977	263	18·8	4545	+ 9.5	8359	8520	1·9	0·3	
96	16 „	11·43	1·97	0·62	5364	267	20·0	4724	+13·5	10,545	10,000	5·5	0·3	
97	19 „	11·82	1·98	0·62	5383	268	20·0	4840	+11·2	10,647	11,050	3·6	0·3	
98	27 „	11·71	1·97	0·62	5554	268	20·7	4812	+15·4	10,963	10,750	2·0	0·3	
99	29 „	11·82	2·10	0·62	5529	268	20·6	4840	+14·2	11,613	11,050	5·1	0·3	

Mean 3·90

* Discharge 71 and onwards were taken on the flood section.

PPER NILE

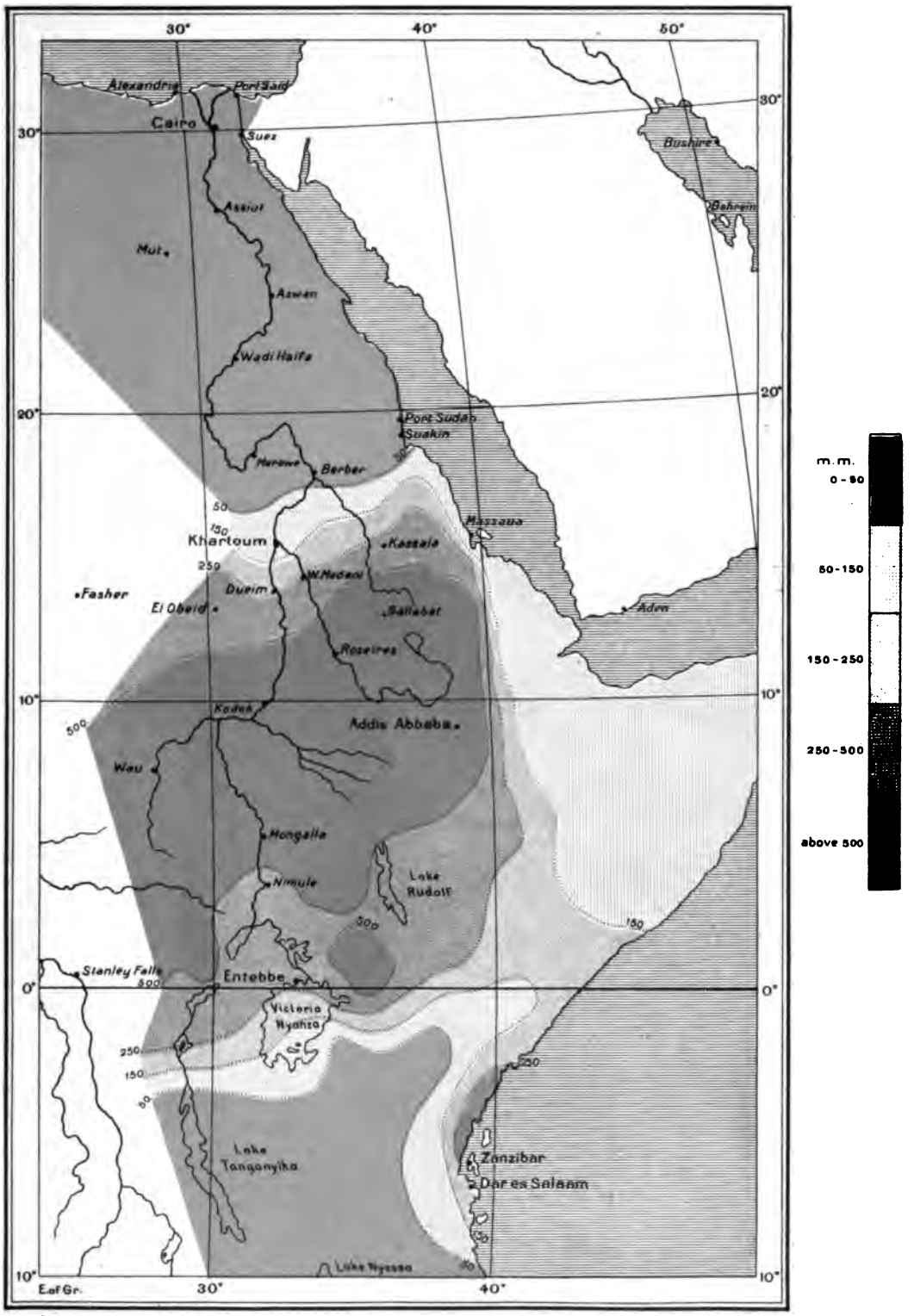
MEAN TOTAL RAINFALL MAR. - MAY.



Survey Dep! Cairo. 1907.

Scale 1:25,000,000

MEAN TOTAL RAINFALL JUNE - SEPT.

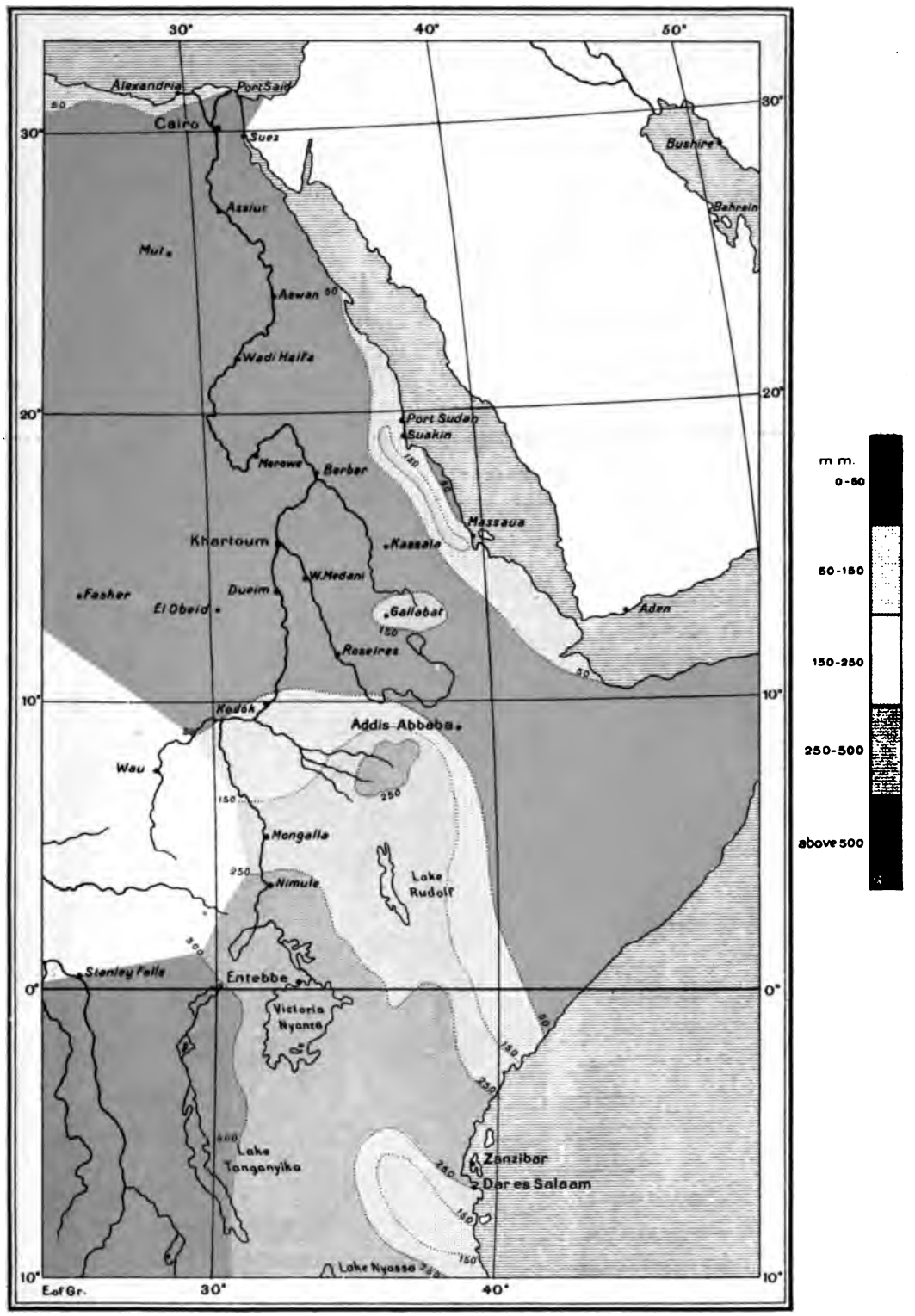


Survey Dep^t Cairo. 1907.

Scale 1:25,000,000

PLATE IIc.

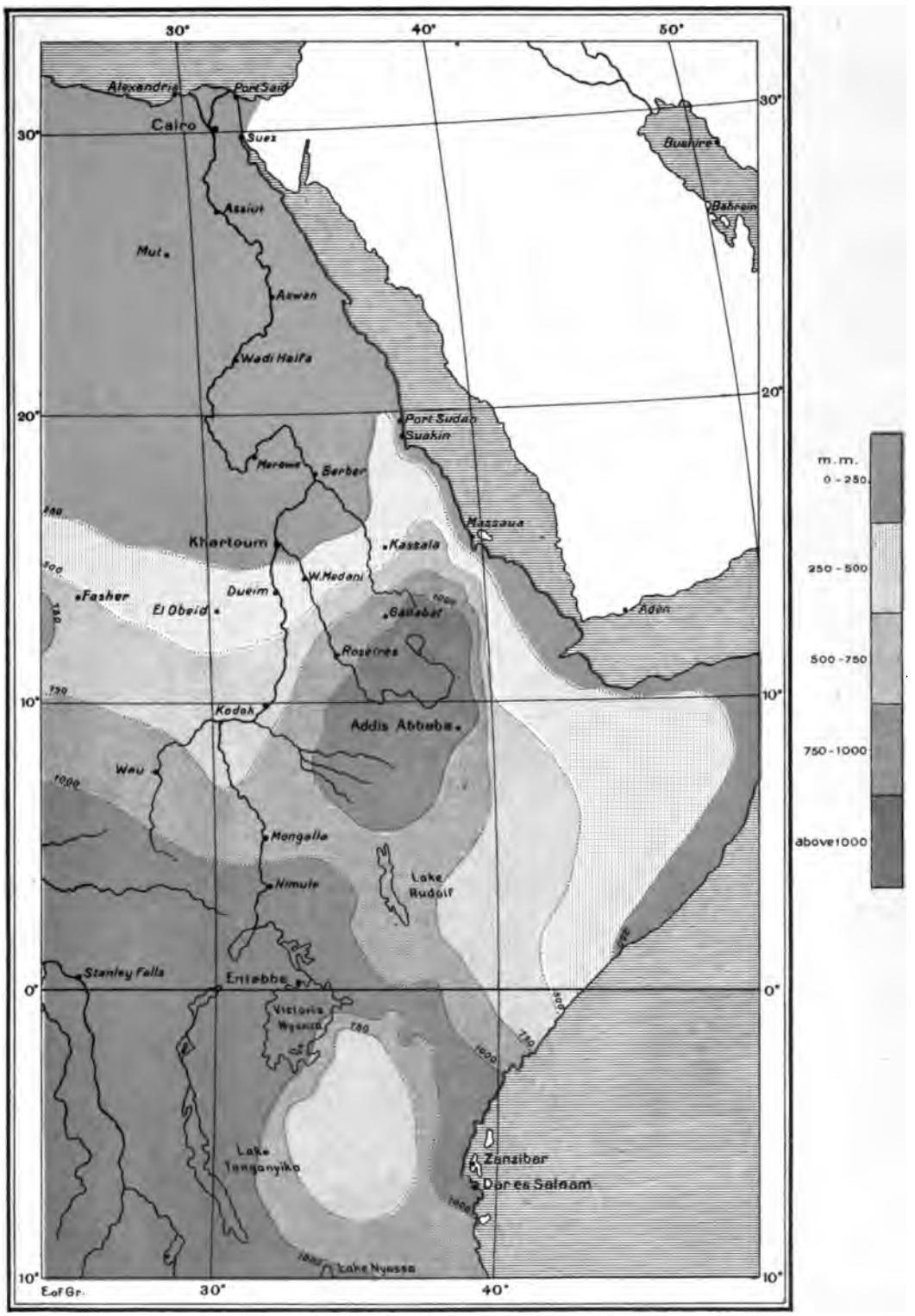
MEAN TOTAL RAINFALL OCT-DEC.



Survey Dept. Cairo. 1907.

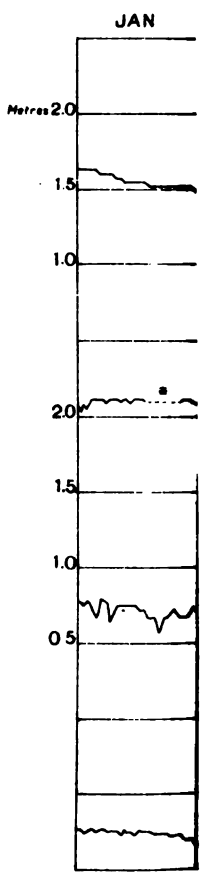
Scale 1:25,000,000

MEAN ANNUAL RAINFALL.

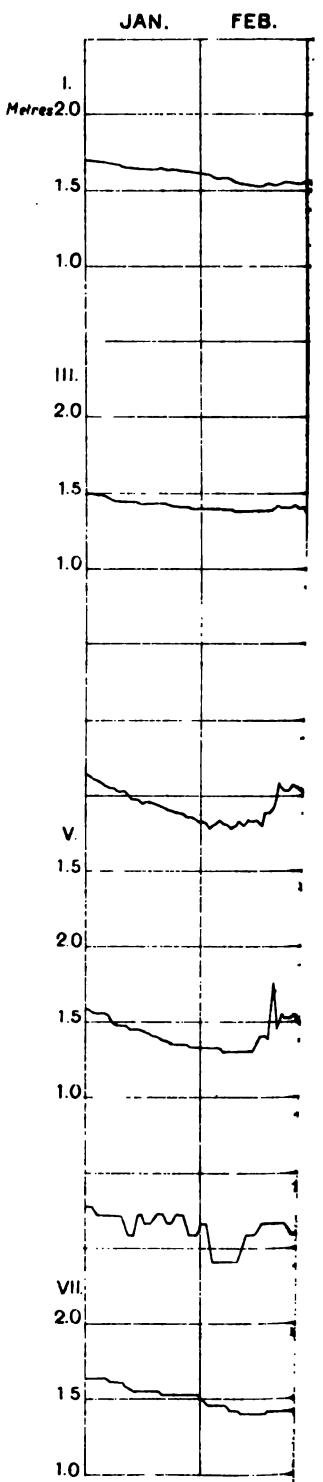


Survey Dep! Cairo.1907.

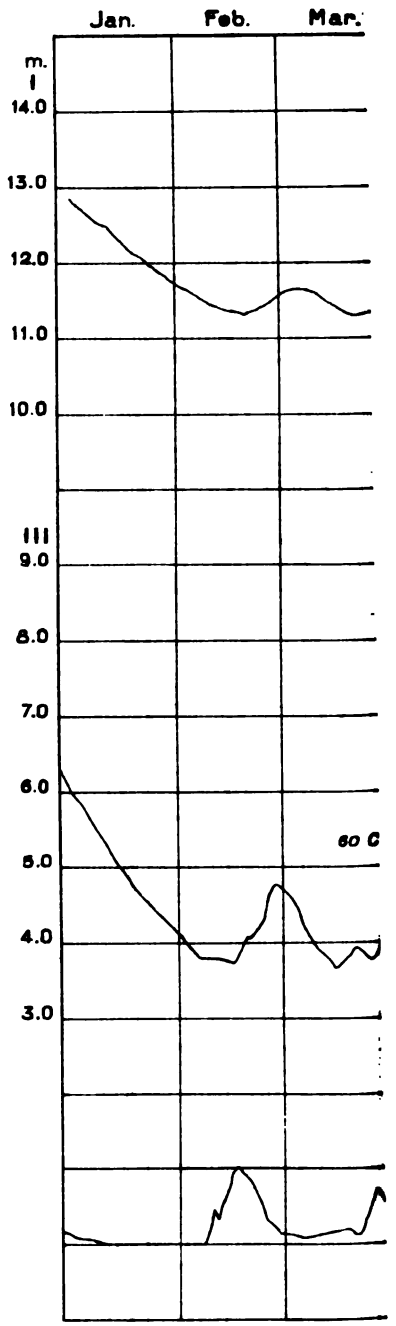
Scale 1:25,000,000



Survey Dept.



Survey Dept. 1907.



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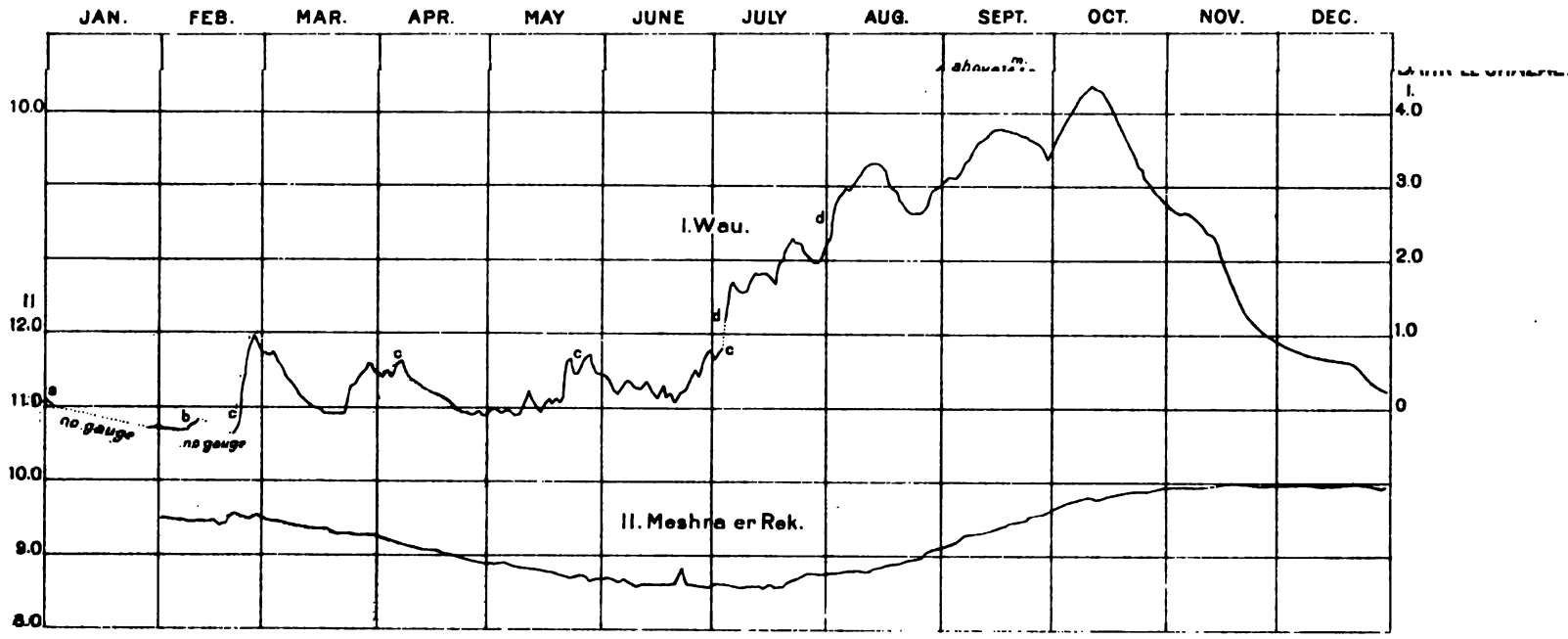
Jan
Feb
Mar
Apr
May

PLATE VI.

WHITE NILE AND BAHR EL GHAZAL GAUGE READINGS 1906.



a and d on Wau proper gauge, b. and c. on two different poles on Jur River when Wau gauge became dry.

* No observations

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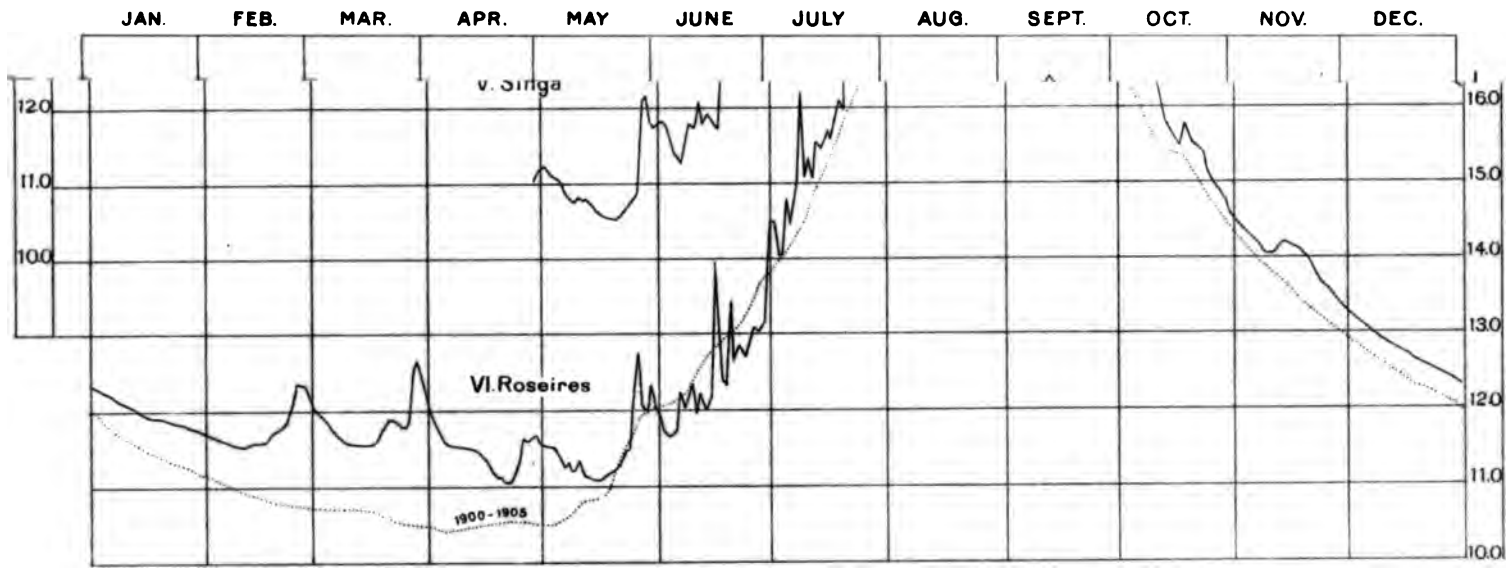
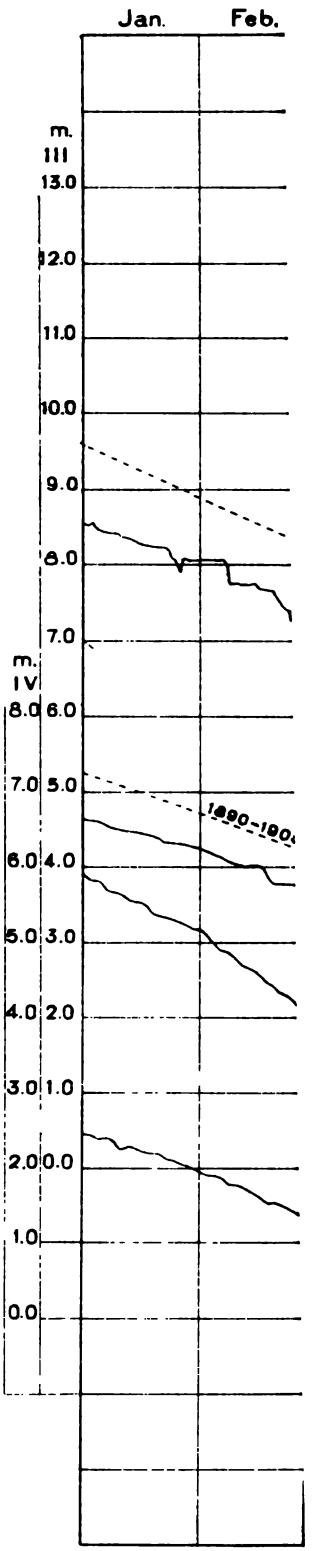
PLATE VII.

BLUE NILE GAUGE READINGS 1906.



Survey Dept. 1907.



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Annual rains, commencing in May, reaching their maximum in August, and rapidly decreasing in September cause a flood which rises rapidly at in July and August, reaches its maximum early in September, falls first rapidly in October, and then more slowly as the low-stage of the river is approached. These tropical rains begin and end with great regularity, and when they are ended, a practically rainless season, lasting for 6 or 7 months, sets in, so it is on the intensity and duration of these tropical rains that the variations of the low-stage level depend.

The first rise of the Nile takes place at Khartoum usually in the last days of May, and while at first the increase of level is slow, it becomes rapid in July and August reaching the maximum about the first week in September on the average. The rains in Abyssinia now are decreasing greatly in intensity, and have practically ceased in the basin of the Blue Nile by the middle of October, so that the fall of the river is now rapid. Craig has discussed the effect of this rapid rise of the Blue Nile flood on the water of the White Nile, and as shown that :—

(1) As soon as the level of the water at Khartoum has risen 2·5 metres, the water surface here and at Dueim begins to rise at very nearly the same rate, since the White Nile valley upstream of Omdurman then contains a practically horinzontal sheet of water.

(2) This reservoir of water continues to rise as long as the Blue Nile rises, and the water coming down the White Nile, which is at this season mostly from the Sobat, is more than sufficient to keep up the level.

(3) The volume of water so stored amounts to about 1,500 millions of cubic metres in an average year.

(4) As the Blue Nile falls, this reserve of water is discharged, increasing the supply and causing levels in the Nile to fall more slowly than in the Blue Nile.

The factors therefore which affect the low-stage levels of the river are :—

(*a*) The intensity of the rainfall in Abyssinia.
(*b*) Its continuance into September and October.
(*c*) The volume stored in the valley of the White Nile.
(*d*) Rainstorms in the months November to April which temporarily raise the water-level.

The first three of these factors are directly connected with the short and heavy rainfall which ceases in October.

The last factor above-mentioned is a disturbing one, but the rare occurrence of heavy rainstorms in the dry season renders it less effective

than in many other rivers. Until the last few years, the want of gauges on the Blue Nile prevented us from ascertaining if such rises occurred, and when records were kept at Khartoum from 1869 to 1883, the readings during the flood period alone were registered.

As from December to April no rain is ordinarily falling in the Blue Nile Basin, it is fair to conclude that such additional supply of water is derived from such occasional rainstorms as we have been discussing. Rainfall in North Uganda will not affect the river level at Wadi Halfa, as the marshy flood-plain of the Bahr el Jebel valley will take up any increased supply, while flood waves in the upper tributaries of the Sobat die out in the long course of that river and the shallow valley of the White Nile.

The average rate of fall of the river at Aswan, deduced from 30 years' observations, is :—

Month.	Fall in cm.	Month.	Fall in cm.
September	58	January	69
October	215	February	64
November	154	March...	63
December	122	April	44

so that the fall in October is that which has most effect in determining the low-stage level. As the river is higher in September than in October, larger volumes of water are passing per second in that month than in October, when the velocity is considerably less, and from the discharge table the proportionate discharge in September, October and November may be taken very approximately as:— 1·4 : 1 : 0·55.

It will be seen from Plate XIII that in several years an abrupt change in the slope of the curve shows that an increased supply of water has passed down the river: 1872, 1875, 1892, 1898 and 1905 may be quoted as the most marked instances of this. If the case of this year may be considered as typical, it is from the Southern Sudan that these rain-bearing depressions come, so that it is most desirable to promote the study of the meteorology of this region. With only a few years' observations at a few stations at present available, but little can yet be done in elucidating their cause.

In Egypt the effect upon the supply was very noticeable, and the following table* shows to how appreciable an extent the supply of the large canals was benefitted:—

Wadi Halfa.						Aggregate discharge of Ibrahimia and Delta Canals in m^3 p. s.			
Date.	Reading.		Discharge m^3 p. s.†		Difference %	Date.	1905	1906	Difference %
	1905	1906	1905	1906					
	m.	m.							
March 10	1·54	1·52	830	790	— 5	April 1	735	780	+ 6
„ 25	1·36	1·60	730	830	+ 14	„ 15	650	740	+ 14
April 10	1·23	1·39	700	745	+ 6	May 1	590	765	+ 30
„ 25	1·14	1·60	670	830	+ 25	„ 15	620	790	+ 28
May 10	1·04	1·30	630	710	+ 12	June 1	540	740	+ 37
„ 27	0·94	1·20	600	690	+ 15	„ 15	590	740	+ 25
June 12	0·93	1·10	590	675	+ 14	July 1	640	780	+ 22
July 1	1·30	1·54	710	830	+ 17	„ 15	780	860	+ 11

Note.—The Delta Barrages were both tightly closed by the end of March in both years.

The Aswan reservoir commenced to supply the region to the north of it on May 1st in 1905, and on May 10th in 1906. The rate of supply was almost exactly the same in both years.

* From the Inspector General of Irrigation for Lower Egypt.

† From a discharge curve derived from the Sarras discharges given in Appendix 1.

APPENDIX

Volumes of the Nile Discharged at Sarras, 1906.

Date.	Gauge.	Mean Velocity m. p. s.	Position of Mean velocity below surface.	Cross Section m².	Width in metres.	Mean depth metres.	Area on unchanged section.	% difference.	Discharge c. m. p. s.	Discharge from curve.	% difference.	No. days to reach Halfa.	Relative gauge readings Halfa.
January.	3·92	0·63	0·65	2476	169·5	16·3	...	...	1570	1630	3·7	0·9	2·60
,,	3·81	0·61	0·65	2566	169·5	15·3	...	...	1567	1560	0·4	1·0	2·56
,,	3·70	0·56	0·65	2545	168	15·2	...	...	1431	1510	5·2	1·0	2·50
,,	3·66	0·59	0·65	2543	168	15·2	...	...	1525	1490	2·3	1·0	2·48
,,	3·61	0·61	0·65	2524	168	15·0	...	...	1549	1460	6·1	0·9	2·45
,,	3·52	0·57	0·65	2521	168	15·0	...	...	1441	1420	1·5	1·0	2·42
,,	3·48	0·56	0·65	2507	168	14·9	...	...	1403	1400	0·2	1·0	2·38
,,	3·35	0·53	0·75	2495	168	14·8	...	...	1323	1340	1·4	1·1	2·32
,,	3·32	0·57	0·65	2491	168	14·8	...	...	1423	1320	7·8	1·0	2·31
,,	3·32	0·55	0·65	2495	167	14·9	...	...	1362	1320	3·2	1·1	2·30
,,	3·27	0·54	0·75	2466	167	14·8	...	...	1323	1300	1·8	1·1	2·26
February.	3·21	0·54	0·65	2461	167	14·7	...	...	1316	1270	3·6	1·1	2·25
,,	3·05	0·50	0·75	2414	166	14·5	...	...	1210	1200	0·8	1·1	2·17
,,	2·93	0·53	0·65	2403	166	14·5	...	...	1210	1160	4·3	1·1	2·11
,,	2·90	0·48	0·65	2399	165	14·5	...	...	1149	1150	0.1	1·2	2·07
,,	2·86	0·47	0·65	2416	165	14·6	...	...	1137	1140	0·3	1·2	2·02
,,	2·76	0·46	0·65	2381	165	14·4	...	...	1094	1090	0·4	1·2	2·00
,,	2·70	0·50	0·65	2374	165	14·4	...	...	1184	1070	10·7	1·2	2·02
,,	2·69	0·46	0·65	2374	165	14·4	...	...	1080	1070	0·9	1·3	1·99
,,	2·52	0·43	0·65	2320	164	14·3	...	...	1003	1020	1·7	1·3	1·77
,,	2·41	0·42	0·65	2308	164	14·1	...	...	970	980	1·0	1·4	1·77
,,	2·36	0·44	0·65	2294	164	14·0	...	...	1001	975	2·7	1·3	1·78
,,	2·34	0·42	0·65	2287	164	14·0	...	...	954	970	1·7	1·4	1·76
March.	2·07	0·36	0·75	2253	164	13·7	...	...	819	880	6·9	1·6	1·64
,,	2·04	0·37	0·65	2242	162	13·8	...	...	824	870	5·3	1·6	1·63
,,	2·00	0·37	0·75	2244	162	13·8	...	...	828	860	3·7	1·6	1·63
,,	1·74	0·34	0·65	2200	162	13·5	...	...	745	800	6·9	1·7	1·54
,,	1·68	0·32	0·65	2232	162	13·8	...	...	723	790	8·5	1·8	1·48
,,	1·71	0·39	0·55	2203	162	13·6	...	...	860	790	8·9	1·5	1·46
,,	1·60	0·36	0·65	2165	162	13·4	...	...	788	770	2·3	1·6	1·44
,,	1·69	0·42	0·66	2179	162	13·5	...	...	914	790	15·7	1·4	1·48
,,	1·80	0·40	0·66	2204	162	13·6	...	...	870	815	6·8	1·5	1·54
,,	1·76	0·38	0·66	2207	162	13·6	...	...	838	810	3·5	1·5	1·49
,,	1·83	0·39	0·66	2226	162	13·7	...	...	857	830	3·2	1·5	1·54
,,	1·90	0·39	0·61	2221	162	13·7	...	...	894	840	6·4	1·4	1·63
,,	1·88	0·39	0·61	2191	162	13·9	...	...	854	830	2·9	1·5	1·58
,,	1·86	0 37	0·61	2209	162	13·6	...	...	821	830	1·1	1·5	1·56
,,	1·79	0·39	0·61	2218	162	13·7	...	...	871	815	6·9	1·5	1·55
April.	1·71	0·38	0·61	2189	162	13·5	...	...	826	790	4·6	1·5	1·51
,,	1·56	0·42	0·61	2145	162	13·2	...	...	910	770	18·2	1·4	1·44
,,	1·51	0·34	0·61	2140	162	13·2	...	...	727	750	3·1	1·7	1·40
,,	1·51	0·35	0·65	2154	162	13·3	...	...	746	750	0·5	1·7	1·40
,,	1·52	0·36	0·65	2139	162	13·2	...	...	765	750	2·0	1·6	1·41
,,	1·50	0·35	0·65	2124	162	13·1	...	...	739	750	1·5	1·7	1·40
,,	1·53	0·35	0·65	2142	162	13·2	...	...	740	750	1·3	1·7	1·40
,,	1·55	0·36	0·65	2135	162	13·2	...	...	777	750	3·6	1·6	1·40
,,	1·55	0·38	0·65	2145	162	13·2	...	...	818	750	9·1	1·5	1·41
,,	1·57	0·33	0·65	2155	162	13·3	...	...	712	760	6·3	1·7	1·42
,,	1·55	0·35	0·65	2141	162	13·2	...	...	759	750	1·2	1·6	1·41
,,	1·55	0·37	0·65	2134	162	13·2	...	...	787	750	4·9	1·6	1·41
,,	1·58	0·34	0·65	2142	162	13·2	...	...	719	760	5·4	1·7	1·41
,,	1·65	0·38	0·65	2162	162	13·2	...	...	819	780	5·0	1·5	1·39
,,	1·75	0·36	0·65	2182	162	13·4	...	...	792	800	1·0	1·6	1·48
,,	1·82	0·41	0·65	2182	162	13·4	...	...	883	830	6·4	1·4	1·57
,,	1·83	0·40	0·65	2189	162	13·5	...	...	867	830	4·5	1·5	1·60
,,	1·82	0·37	0·65	2185	162	13·5	...	...	803	830	3·3	1·6	1·57

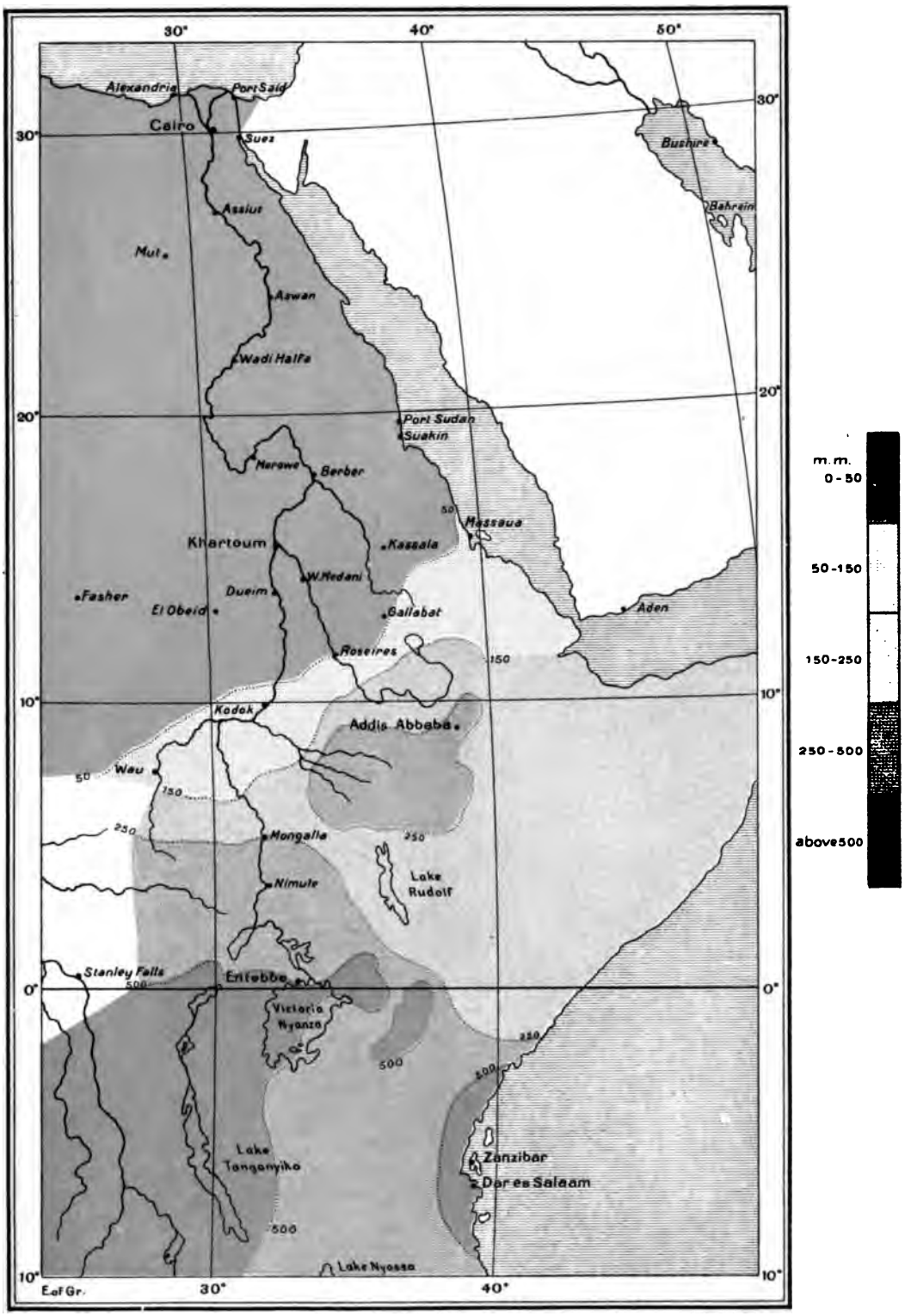
APPENDIX (*continued.*)

No.	Date.	Gauge.	Mean velocity m. p. s.	Position of mean velocity below Surface.	Cross section m².	Width in metres.	Mean depth metres.	Area on unchanged section.	% difference.	Discharge c. m. p. s.	Discharge from curve.	% difference.	No. days to reach Halfa.	Relative gauge readings Halfa.
57	1 May.	1·51	0·37	0·61	2143	162	13·2	...	...	787	750	4·9	1·6	1·41
58	2 ,,	1·49	0·36	0·61	2134	163	13·2	...	...	763	740	3·1	1·6	1·38
59	3 ,,	1·44	0·36	0·61	2125	163	13·1	...	...	765	730	4·8	1·6	1.35
60	10 ,,	1·28	0·35	0·61	2091	163	12·9	...	...	728	700	4·0	1·7	1·28
61	11 ,,	1·25	0·35	0·61	2102	163	12·9	...	...	761	700	8·7	1·6	1·24
62	12 ,,	1·19	0·32	0·61	2083	163	12·9	...	...	663	690	3·9	1·8	1·20
63	15 ,,	1·12	0·33	0·61	2088	163	12·9	...	...	696	690	0·9	1·7	1·16
64	17 ,,	1·14	0·33	0·61	2102	163	12·9	...	...	699	670	4·3	1·7	1·16
65	19 ,,	1·09	0·30	0·61	2105	161·5	13·0	...	...	630	660	4·5	1·9	1·18
66	22 ,,	1·11	0·33	0·61	2088	161·5	13·0	...	...	692	670	3·3	1·7	1·20
67	24 ,,	1·14	0·34	0·61	2100	161·5	13·0	...	...	722	670	7·8	1·7	1·18
68	25 ,,	1·12	0·31	0·61	2098	161·5	13·0	...	...	655	670	2·2	1·8	1·20
69	27 ,,	1·10	0·33	0·61	2091	161·5	12·9	...	...	680	670	1·5	1·8	1·20
70	29 ,,	1·06	0·30	0·61	2086	161	12·9	...	...	623	660	5·6	2·0	1·18
71*	7 June.	0·97	0·27	0·60	2249	215	10·5	2223	+ 1·1	600	640	6·3	2·1	1·14
72	15 ,,	0·98	0·27	0·60	2251	215	10·5	2223	+ 1·3	600	640	6·3	2·1	1·20
73	16 ,,	1·06	0·31	0·60	2256	215	10·4	2244	+ 0·5	707	700	1·0	1·8	1·20
74	18 ,,	1·27	0·31	0·60	2326	218	10·6	2288	+ 1·7	701	730	4·0	1·8	1·35
75	22 ,,	1·58	0·34	0·60	2363	219	10·8	2353	+ 0·4	813	810	0·4	1·7	1·50
76	23 ,,	1·62	0·34	0·60	2351	219	10·7	2353	...	803	815	1·5	1·7	1·5
77	26 ,,	1·60	0·36	0·60	2347	219	10·7	2353	...	840	810	3·7	1·6	1·5
78	27 ,,	1·62	0·35	0·60	2346	219	10·7	2353	...	819	815	0·5	1·6	1·5
79	1 July.	1·71	0·36	0·62	2381	220	10·8	2376	...	862	830	3·9	1·6	1·
80	2 ,,	1·78	0·37	0·62	2435	220	11·0	2398	+ 1·5	898	860	4·4	1·5	1·
81	3 ,,	1·86	0·37	0·62	2473	220	11·2	2419	+ 2·2	917	880	4·2	1·5	1·
82	4 ,,	2·00	0·39	0·62	2516	224	11·2	2441	+ 3·1	986	920	7·2	1·5	1·
83	7 ,,	2·07	0·40	0·62	2523	224	11·2	2463	+ 2·4	1010	940	7·5	1·4	1·
84	8 ,,	2·33	0·41	0·62	2549	225	11·3	2507	+ 1·7	1031	1030	0·1	1·4	1
85	10 ,,	2·45	0·42	0·62	2593	225	11·5	2540	+ 2·1	1075	1070	0·5	1·4	1
86	11 ,,	2·53	0·42	0·62	2614	225	11·6	2558	+ 2·5	1099	1100	0·1	1·4	2
87	15 ,,	2·85	0·44	0·62	2645	226	11·7	2630	+ 0·6	1151	1225	6·0	1·3	2
88	22 ,,	5·12	0·76	0·62	3196	238	13·4	3153	+ 1·4	2444	2420	1·0	0·8	3
89	24 ,,	5·51	0·82	0·63	3247	240	13·5	3248	...	2658	2670	0·5	0·7	[illegible]
90	27 ,,	6·12	0·88	0·63	3432	241	14·3	3392	+ 1·2	3018	3100	2·6	0·7	[illegible]
91	1 August.	7·21	1·07	0·62	3865	244	15·8	3659	+ 5·6	4154	3860	7·6	0·5	[illegible]
92	3 ,,	7·63	1·16	0·62	3925	246	15·9	3758	+ 4·4	4559	4510	1·1	0·5	[illegible]
93	5 ,,	8·28	1·35	0·62	4006	248	16·4	3932	+ 1·9	5396	5200	3·8	0·4	[illegible]
94	8 ,,	9·90	1·67	0·62	4266	256	16·6	4337	— 1·6	7112	7550	5·8	0·3	[illegible]
95	11 ,,	10·60	1·70	0·62	4977	263	18·8	4545	+ 9.5	8359	8520	1·9	0·3	[illegible]
96	16 ,,	11·43	1·97	0·62	5364	267	20·0	4724	+13·5	10,545	10,000	5·5	0·3	[illegible]
97	19 ,,	11·82	1·98	0·62	5383	268	20·0	4840	+11·2	10,647	11,050	3·6	0·3	[illegible]
98	27 ,,	11·71	1·97	0·62	5554	268	20·7	4812	+15·4	10,963	10,750	2·0	0·3	[illegible]
99	29 ,,	11·82	2·10	0·62	5529	268	20·6	4840	+14·2	11,613	11,050	5·1	0·3	[illegible]

Mean 3·90

* Discharge 71 and onwards were taken on the flood section.

MEAN TOTAL RAINFALL MAR. - MAY.



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MEAN TOTAL RAINFALL JUNE – SEPT.

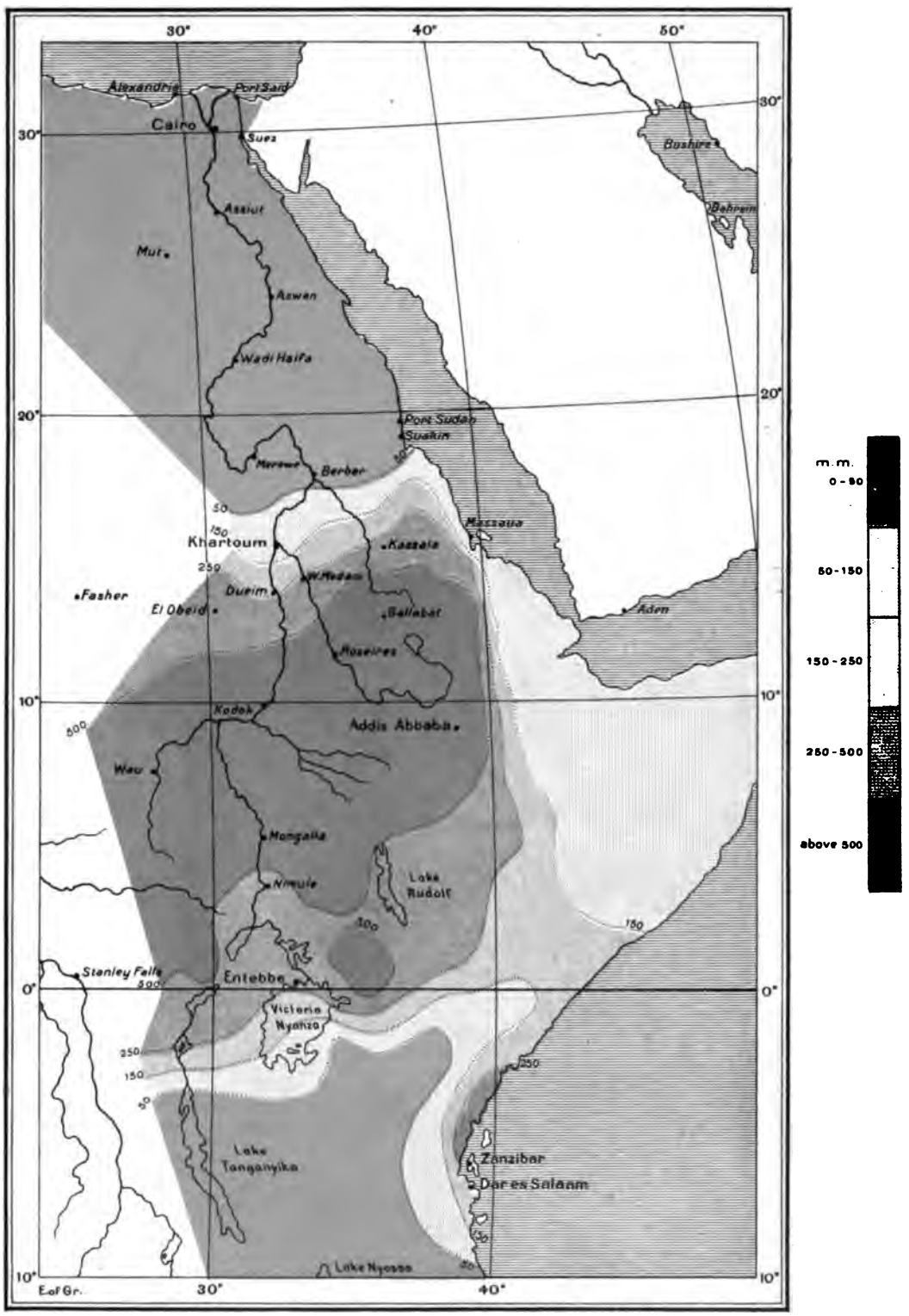

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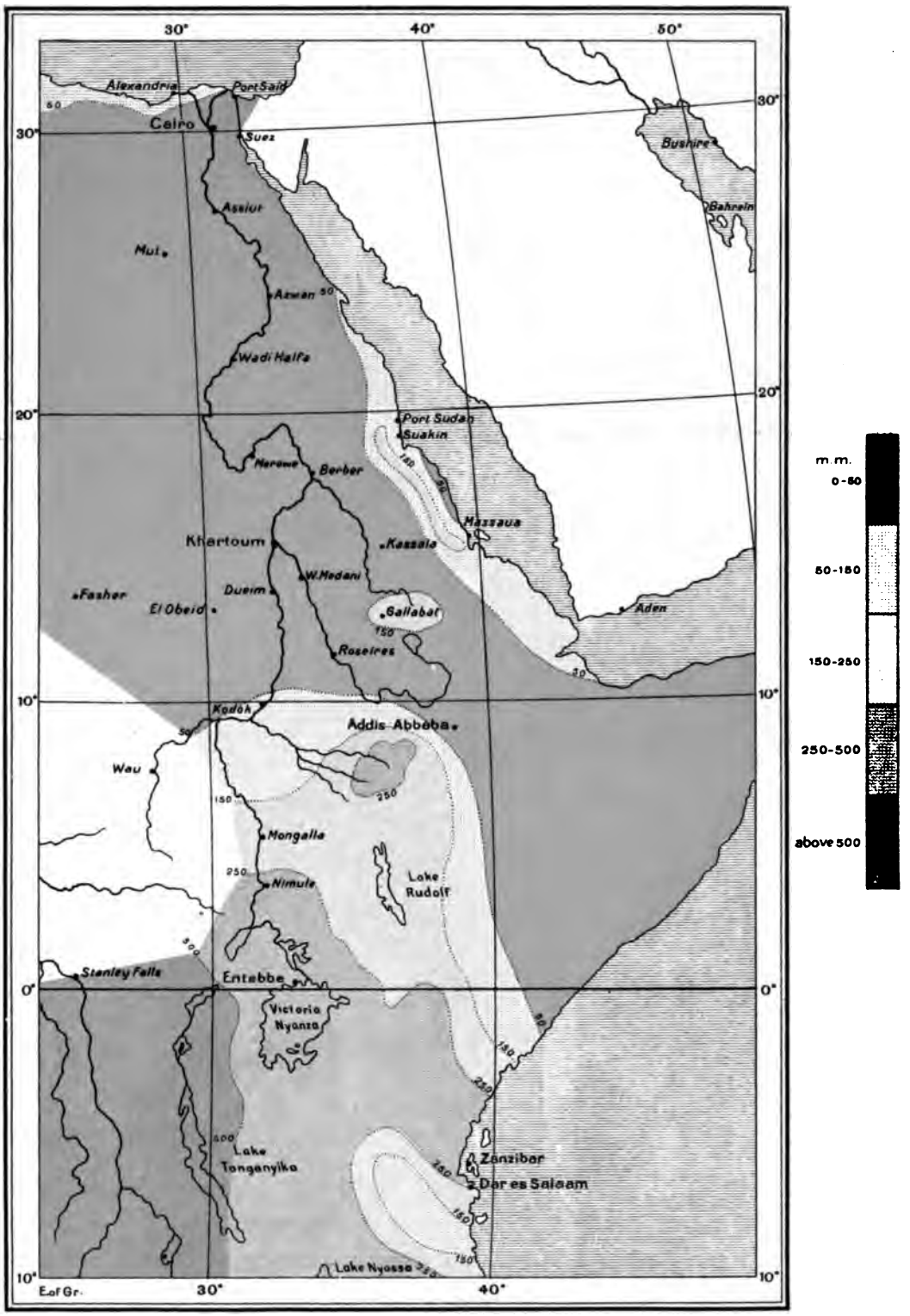
PLATE IIc.

MEAN TOTAL RAINFALL OCT-DEC.



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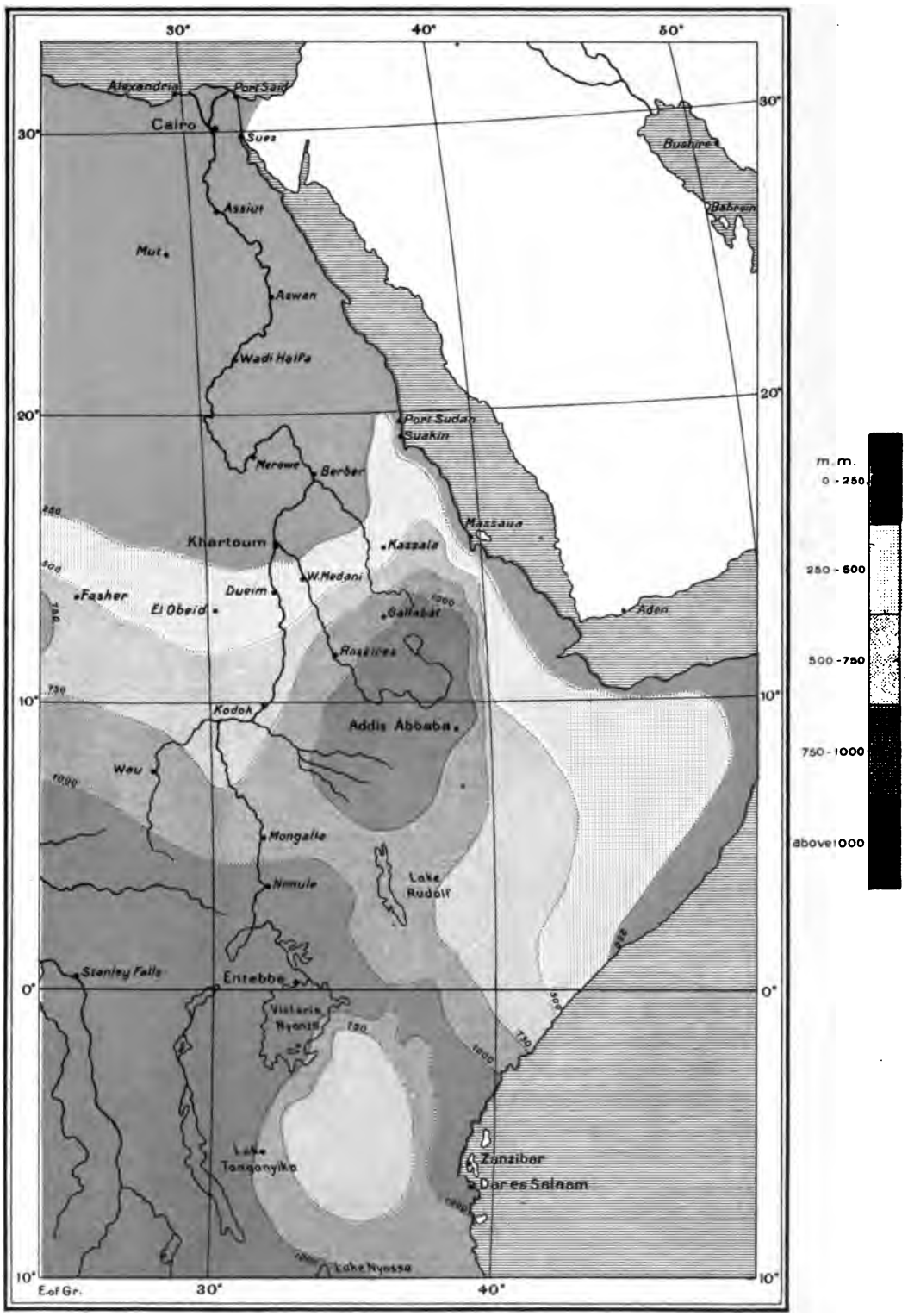
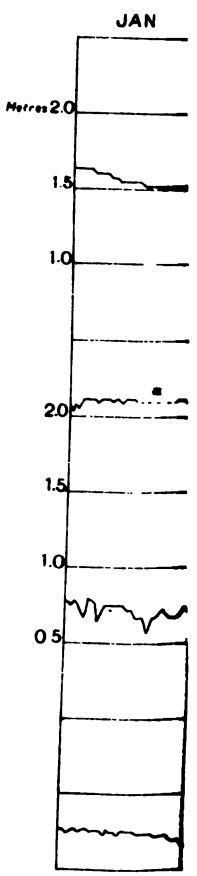
Scale 1:25,000,000

MEAN ANNUAL RAINFALL.



Survey Dep! Cairo. 1907.

Scale 1:25,000,000



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